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False memories planted in a mouse's brain

NewScientist

WEEKLY March 14 - 20, 2015

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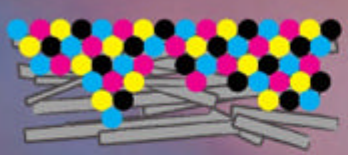

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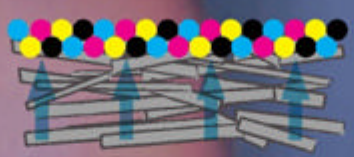

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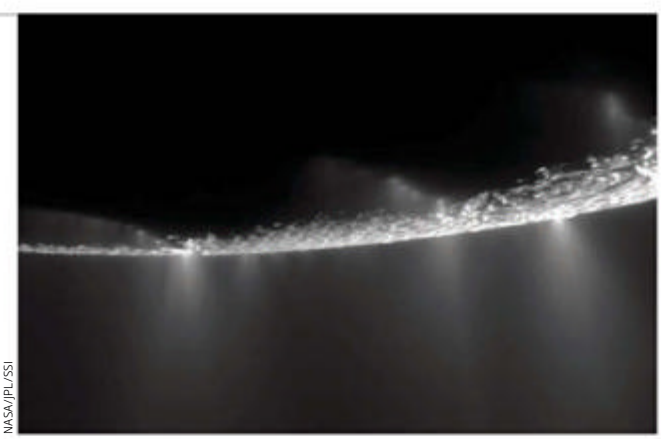

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CONTACTS
Contact us
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Who's who
newscientist.com/people

General & media enquiries
enquiries@newscientist.com

Editorial
Tel 781 734 8770
news@newscientist.com
features@newscientist.com
opinion@newscientist.com

Picture desk
Tel +44 (0) 20 7611 1268

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STEVEN VIDLER/CORBIS

The war on history

We can't stop vandalism. But we can try to make it pointless

YOU don't have to be a historian or an archaeologist to feel anger and despair at the destruction of Nimrud, ancient capital of Assyria, by the self-styled Islamic State. UNESCO director-general Irina Bokova has described it as a "war crime". It feels like a crime against humanity.

As so often with ISIS, it is an act seemingly designed to show that the militants are unconstrained by the bounds most of humanity observes. Who would not respect such a unique location, or the irreplaceable artefacts destroyed at the Mosul Museum in Iraq?

But in fact ISIS, for all its ostentatious extremism, is just the latest in a long line of vandals. Egregious examples in the past century include the Nazi book burnings of the 1930s and the Taliban's shelling of the Buddhas of Bamiyan, Afghanistan, in 2001 – spared even by Genghis Khan.

Destroying stores of knowledge is a tactic favoured by those who seek to press home a fundamentalist message. "Those who don't know history are destined to repeat it," said the 18th-century philosopher Edmund Burke. For those who want to create their own fundamentalist pastiche of the past, obliterating the lessons of history is an attractive idea.

What can be done? It is too late for Nimrud (see page 10). But we can do more to protect antiquities in future. There is a strong suspicion that ISIS, which like so many despotic regimes is not as ideologically pure as it pretends, is profiting from the sale of looted art and artefacts. Last month, the UN Security Council passed a resolution obliging all member states to improve their capacity to seize looted antiquities from ISIS-controlled territory. The UK, for its part, could finally ratify the 1954 Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict – more than a decade after it agreed to do so.

Technology can help, too. It's no substitute for physically securing a site, but remote sensing technologies can at least record sites at risk of destruction. For example, drone-mounted rigs makes 3D scanning of sites relatively cheap and easy.

Such scans might even make rebuilding easier. Attempts to reconstruct the Bamiyan Buddhas have stalled partly because no one can agree on how to go about it. Today, more than ever before, we have the tools to ensure history cannot be effaced altogether or forever. We should vow to use them, before Nimrud's destruction itself passes into forgotten history. ■

The furry dice of fate

We're celebrating this special issue on chance by giving you randomness. For the first time, the printed magazine has four different cover designs. If you are in the UK, the cover you have is largely down to chance, like so much in life (see page 28). But not everything is a lottery: the articles are the same for all.

SIU CHIU/REUTERS

Poultry measures

Bird flu flaring up again

BIRD flu is on the march around the world. One strain, the H5N1 virus, has been endemic in birds across Eurasia and Africa since 2006. Now, with veterinary controls in Egypt weakened by recent turmoil, increased outbreaks in poultry have caused a surge in human infections. H5N1 was confirmed in 46 Egyptians in January 2015, with another 36 reported so far in February. The virus kills about half of those infected.

Now another bird flu is poised to repeat H5N1's international rampage. H7N9 started killing people in China in 2013, and the third H7N9 outbreak began in November. More than 100 cases have been reported, all in China so far.

But that may not last. Yi Guan of the University of Hong Kong and his colleagues report this week that H7N9 gene sequences from poultry across south-east China suggest the virus is spreading with the live poultry trade and diversifying genetically (*Nature*, DOI: 10.1038/nature14348). In 2006, his team found H5N1 spreading the same way.

Like H5N1, Guan warns that H7N9 is now likely to spread westward beyond China. Human cases in north-west China show it has already crossed the country.

Meanwhile, H5N1 has finally invaded North America in a hybridised form with other bird flu viruses. It arrived with wildfowl on the west coast in December and is moving rapidly down the Mississippi valley, a migratory flyway. Its danger to people in this form is unknown.

Trade pact warning

TRADE or environment? A parliamentary committee in the UK has warned that a trade agreement between the US and the European Union could weaken environmental regulations.

The Transatlantic Trade and Investment Partnership, TTIP, is being negotiated to lift barriers to trade across the pond. But the differences in safety and environmental standards between the US and the EU could allow private companies to sue governments if environmental laws disrupt business opportunities, and might end up undermining or diluting existing laws designed to protect the public and the environment.

"Boosting transatlantic trade must not come at the cost of losing environmental protection"

Boosting transatlantic trade must not come at the cost of losing hard-won environmental and public-health protections, says Joan Walley, chairwoman of the Environmental Audit Committee, which produced the report. "Europe must retain its right to regulate."

The report says EU states should engage with environmental groups and agencies to ensure environmental issues are properly considered, and should push to get representation for these groups on the proposed regulatory council for the trade deal. And it urges the UK government to allow the public to scrutinise the agreement before it is a done deal. So far the negotiations have been private.

The ISIS Twitterati

WE ALREADY knew ISIS was pretty tech-savvy. The Islamist extremist group is adept at spreading propaganda on social media. Now tens of thousands of Twitter accounts owned by ISIS supporters have been uncovered.

A report by non-profit group the Brookings Institution in Washington DC has found up to 70,000 accounts that seem to support ISIS. The majority of the accounts were created in 2014, tweet from within Syria or Iraq, and have Arabic, English or French as their main language. A typical account is more active than the average Twitter user, with more than 1000 followers and about seven tweets a day.

Since last summer, Twitter has been more aggressive about suspending accounts associated with ISIS, but the Brookings Institution warns that this might make it harder for us to work out what ISIS is up to. "If every single ISIS supporter disappeared from Twitter tomorrow, it would represent a staggering loss of intelligence," says the report.

For more on ISIS, see page 10

OLIVIA HARRIS/REUTERS

The enigma and sadness linger

MH370 still baffling

THE mystery continues. The most comprehensive report yet into the disappearance of Malaysia Airlines flight 370 in March 2014 has brought passengers' families and the world no closer to understanding what happened.

The biggest revelation in the report, by a team of international investigators, was that the battery in one of the underwater locator beacons had not been replaced despite having an expiry date of

December 2012. Even so, the report notes that this doesn't rule out the beacon being able to function to an extent.

Moreover, a second beacon in the cockpit voice recorder had a properly serviced battery and should have worked as designed, Malaysia Airlines pointed out in a statement.

The report outlines everything known about the plane, from its uneventful take-off to the mysterious change of direction over Indonesia, but finds no evidence for any particular theory. It also finds no grounds to suspect any of the crew members.

Curiosity in a fix

OW, MY arm! NASA's Curiosity rover has been out of action on Mars since 27 February after a short circuit triggered safety alerts on board. Mission controllers ordered the rover to down tools until they diagnosed the problem. Now they've traced the short to the drill on Curiosity's robotic arm and say it should be up and running again this week.

With robot doctors in short supply on Mars, Curiosity may have to take it easy when it gets back to work. Its drill works by both rotating and hammering against the Martian surface, but its movements could be restricted in the future.

"The most likely cause is an intermittent short in the percussion mechanism of the drill," said project manager Jim Erickson. "After further analysis to confirm that diagnosis, we will be analysing how to adjust for that in future drilling."

The short circuit occurred during Curiosity's sixth drill since it arrived on Mars in 2012. Sampling the Martian soil helps NASA look for evidence of ancient rivers and other signs that the planet was once habitable.

Blasted oil wells

KABOOM! Imagine 13 million blasts over the next six to seven years. That's what Atlantic marine life will have to put up with if noisy oil exploration goes ahead.

A letter signed by 75 scientists and sent last week to US president Barack Obama says that the loud airgun blasting used to detect oil and gas deposits beneath the seabed will wreak havoc on marine life along the US Atlantic seaboard. "The magnitude of the proposed seismic activity is likely to have significant, long-lasting and widespread impacts on the reproduction and survival of fish and marine mammals," it says.

A framework to allow such seismic testing received the go-ahead last year from the US Department of the Interior, and nine applications to prospect are now under review. The scientists call on Obama to use his presidential powers to intervene and call a halt to the testing programme.

"The ocean is a world of sound, and marine mammals and fish rely on it for feeding, breeding and maintaining social bonds," says Michael Jasny of the Natural Resources Defense Council, an environmental group in Washington DC that backed the scientists' call.

Apple Watch is just half the story

IT'S time. On Monday, Apple unveiled its smart watch. The Californian company's device will finally be on sale from 24 April, costing between $349 and $17,000 in the US and between £299 and £13,500 in the UK. But Apple also launched a project that could be even bigger: one with the potential to completely change the way we learn about health.

That project is ResearchKit. This software runs on iPhones, can tap into Apple Watch data and allows users to participate directly in medical research studies. A suite of five associated apps, live now, links users to studies on Parkinson's disease, diabetes, asthma, breast cancer and heart disease.

Apple has said that it will never see the data itself: the company has created a channel for funnelling the information from its hundreds of millions of customers directly into the hands of health researchers.

"Having one of these things on their wrist, you can pick up how someone's sleep is," says Patricia Ganz of the Fielding School of Public Health at the University of California, Los Angeles. She worked with Apple to build one of the ResearchKit apps, called Share the Journey, through which women who have undergone treatment for breast cancer can share their experiences of coping with symptoms. "These sensors have the potential to pick up functional aspects of people's everyday life," says Ganz.

ROBERT GALBRAITH/REUTERS

So smart it does research science

60 SECONDS

A predator's return

Watch out, Bambi. The Eurasian lynx could soon be reintroduced to forests in Cumbria, Aberdeenshire and Norfolk to help control escalating numbers of UK deer. A public consultation is to be held on the return of the cat, 1300 years after it went extinct in the country.

Repulsive lizards

Geckos have a fresh trick. Slow-motion video footage shows water droplets launching themselves away from a gecko's body like popping popcorn. The phenomenon, dubbed "geckovescence", is caused by a dense array of minuscule, hair-like structures called spinules, and could help keep the lizards dry (*Journal of the Royal Society Interface*, DOI: 10.1098/rsif.2014.1396).

Window of fertility

Timing is everything. A test that could boost IVF success by detecting a woman's most fertile period is being trialled. The technique measures gene activity in the uterus lining to identify the period of two to four days when chemical signals are released to encourage embryos to implant. Missing this window can be a cause of failed IVF procedures.

A race in the sun

It's an idea with wings. A pioneering attempt to fly around the world powered solely by the sun began on Monday. The solar-powered aircraft Solar Impulse 2 took off from Abu Dhabi and will do about 25 days' worth of flying over five months.

Low target

It's not going to be enough. The EU has committed to a 40 per cent cut in greenhouse gas emissions by 2030, compared with 1990 levels. The pledge is in preparation for the UN climate summit in Paris in December. But a report led by UK economist Nicholas Stern says the EU targets, and those promised by US and China, will not be enough to avert catastrophic climate change.

False memories conjured in sleep

We can now implant memories into mice, but could we do it in humans?

Jessica Hamzelou

SLEEPING minds: prepare to be hacked. For the first time, conscious memories have been implanted into the minds of mice while they sleep. The same technique could one day be used to alter memories in people who have undergone traumatic events.

When we sleep, our brain replays the day's activities. The pattern of brain activity exhibited by mice when they explore a new area during the day, for example, will reappear, speeded up, while the animal sleeps. This is thought to be the brain practising an activity – an essential part of learning. People who miss out on sleep do not learn as well as those who get a good night's rest, and when the replay process is disrupted in mice, so too is their ability to remember what they learned the previous day.

Karim Benchenane and his colleagues at the Industrial Physics and Chemistry Higher Educational Institution in Paris, France, hijacked this process to create new memories in sleeping

"It's a bit worrying. It implies you could make someone want something even if they didn't really"

mice (*Nature Neuroscience*, doi.org/2p5). The team targeted the rodents' place cells – neurons that fire in response to being in or thinking about a specific place. These cells are thought to help us form internal maps; last year their discoverers won a Nobel prize.

Benchenane's team used electrodes to monitor the activity of mice's place cells as the animals explored an enclosed arena, and in each mouse they identified a cell that fired only in a certain

FLORIAN LÖBERMANN/WESTEND61/CORBIS

We can remember it for you

arena location. Later, when the mice were sleeping, the researchers monitored the animals' brain activity as they replayed the day's experiences. A computer recognised when the specific place cell fired; each time it did, a separate electrode would stimulate brain areas associated with reward.

When the mice awoke, they made a beeline for the location represented by the place cell that had been linked to a rewarding feeling in their sleep. A brand new memory – linking a place with reward – had been formed.

It is the first time a conscious memory has been created in animals during sleep. In recent years, researchers have been able to form subconscious associations in sleeping minds – for example, smokers can learn to associate cigarettes with the smells of rotten eggs and fish in their sleep.

"It's unbelievably hard to do any of this… but it's not impossible that it could happen"

Previous work suggested that if this kind of subconscious learning had occurred in Benchenane's mice, they would have explored the arena in a random manner, perhaps stopping at the reward-associated location. But these mice headed straight for the location, suggesting a conscious memory. "The mouse develops a goal-directed behaviour to go towards the place," says Benchenane. "It proves that it's not an automatic behaviour. What we create is an association between a particular place and a reward that can be consciously accessed by the mouse."

"The mouse is remembering enough abstract information to think 'I want to go to a certain place', and go there when it wakes up," says neuroscientist Neil Burgess at University College London. "It's a bigger breakthrough [than previous studies] because it really does show what the man in the street would call a memory – the ability to bring to mind abstract knowledge which can guide behaviour in a directed way."

LANDMARK MEDIA

Inception collides with reality

NOW IT'S OUR TURN

It's a familiar feat from films such as *Inception* and *Total Recall*, but will we ever really be able to plant a memory in someone else's mind as they sleep?

Karim Benchenane at the Industrial Physics and Chemistry Higher Educational Institution in Paris, France, who implanted new memories into mice while they snoozed (see main story), hopes his technique can be developed to alter problematic memories in people. The idea is to attach good thoughts to bad memories, such as those that linger after traumatic experiences. "If you can identify where in the brain a person is reactivating a phobia-associated experience, you might be able to create a positive association," he says.

You could probably use the same approach to alter a person's memory to your own advantage.

Evidence suggests that single neurons can represent specific people in the brain – such cells have been termed "Jennifer Aniston cells" after a woman in a study was found to have one brain cell that only fired in response to images of the actress (*Nature*, doi.org/cmzdk9). If you could identify a neuron that represents you in someone else's brain and then stimulate areas of the brain that create a rewarding feeling every time that neuron fires, you might – in theory – be able to make that person like you more. "The fact that you can do it during sleep is a bit worrying, in that it implies that you could make somebody want something even if they didn't really," says Neil Burgess at University College London.

It is much more difficult to create an entirely new memory from scratch. Benchenane's team drew on the mice's existing memories of space and altered them. "It's not like they have created a whole new space that the animal is exploring in its head," says Loren Frank at the University of California, San Francisco. "Real experiences involve all of our senses and movement through space, and people, places and things," he says. "We are nowhere near recreating that richness – what we can do is take advantage of it and modify it."

These modifications could be for better or worse, says Frank. "There are a few ways of thinking about this – there's the medical application, and there's the more Orwellian application, where the government gets inside people's heads and starts to control them," he says. "It's unbelievably hard to do any of this, so I'm not deeply worried about it, but it's not impossible that it could happen."

This must be the place

Benchenane doesn't think the technique can be used to implant many other types of memories, such as skills – at least for the time being. Spatial memories are easier to modify because they are among the best understood.

His team's findings also provide some of the strongest evidence for the way in which place cells work. It is almost impossible to test whether place cells function as an internal map while animals are awake, says Benchenane, because these animals also use external cues, such as landmarks, to navigate. By specifically targeting place cells while the mouse is asleep, the team were able to directly test theories that specific cells represent specific places.

"Even when those place cells fire in sleep, they still convey spatial information," says Benchenane. "That provides evidence that when you've got activation of place cells during the consolidation of memories in sleep, you've got consolidation of the spatial information."

Benchenane hopes that his technique could be developed to help alter people's memories, perhaps of traumatic events (see "Now it's our turn", above).

Loren Frank at the University of California, San Francisco, agrees. "I think this is a really important step towards helping people with memory impairments or depression," he says. "It is surprising to me how many neurological and psychiatric illnesses have something to do with memory, including schizophrenia and obsessive compulsive disorder."

"In principle, you could selectively change brain processing during sleep to soften memories or change their emotional content," he adds. ■

Can we save history from ISIS vandals?

Catherine Brahic

THE Islamic State's latest propaganda video shows fighters smashing statues and artefacts that are thousands of years old in the Mosul Museum, Iraq. The destruction is shocking, but maybe it is not random.

Archaeologist Katharyn Hanson of the University of Pennsylvania in Philadelphia has examined the video and points out that valuable objects are missing. She says that despite what the IS fighters say, they are not destroying everything.

The missing objects will likely be sold for a healthy profit on the black market, using international crime networks. Just how much money ISIS generates for its military campaign from looted art is still debated. Some believe the sale of ancient art is a key revenue stream for the terrorist group. Others, including Hanson, argue that ISIS makes far more money from oil stolen from pipelines and ransoms paid for hostages. Either way, treasures are being lost forever.

Following the Mosul Museum rampage, ISIS bulldozed the nearby ancient city of Nimrud in Iraq. Last month, ISIS reportedly also burned thousands of rare manuscripts and documents from Mosul libraries. Looting and the destruction of cultural artefacts and archaeological sites has been rife for years in Iraq and more recently in Syria.

Now ISIS is attempting to wipe out ethnic and religious minorities that do not adhere to its own world view. "They [ISIS] are literally going to annihilate anything that does not fit their framework," Hanson says. "I think the intent is to terrorise communities and demonstrate power."

"Looting is happening everywhere and anyone with a shovel is doing it," says Michael Danti, an archaeologist at the University of Boston. "All the jihadi groups are doing it, factions within the Syrian regime are doing it, and there are stories of factions within the Syrian opposition doing it. It's very tempting, and lucrative. Some people are trying to feed their families, others are buying weapons."

Danti says most of the looted artefacts coming out of Iraq and Syria end up in Lebanon and Turkey. Then they are exported to Europe through countries with more porous borders, like Portugal and Cyprus. "Once it's in the EU it's a little easier to get false accreditation, so it can be imported 'legally', and moved on to the major centres like London and New York," he says.

"Looting is happening everywhere, and everyone with a shovel is doing it, including the jihadis"

The objects range from sculptures and mosaics to inscriptions and coins, and can fetch up to $60,000 at legal auctions. "You name it, I've seen it all," says Danti. "The stuff we're seeing is the tip of an iceberg. The really, really valuable stuff goes to high-end criminals and gets sold directly to the buyers."

So what can be done to prevent further looting? Several research groups are using technology and local contacts to try and document and save some of the treasures. For example, Hanson is leading the Safeguarding the Heritage of Syria Initiative (SHOSHI) to monitor the extent of the damage, train people on the ground to document and preserve remaining archaeological sites, and to get them more equipment.

Nimrud was the second of four ancient Assyrian capitals to be destroyed by ISIS, alongside Nineveh, with reports that a third, Khorsabad, has been attacked, too. But Hanson acknowledges that there's only so much SHOSHI can do. "We knew Nimrud was going to come eventually," she says. "I cannot believe that we never sent a 3D scanner to any of these sites."

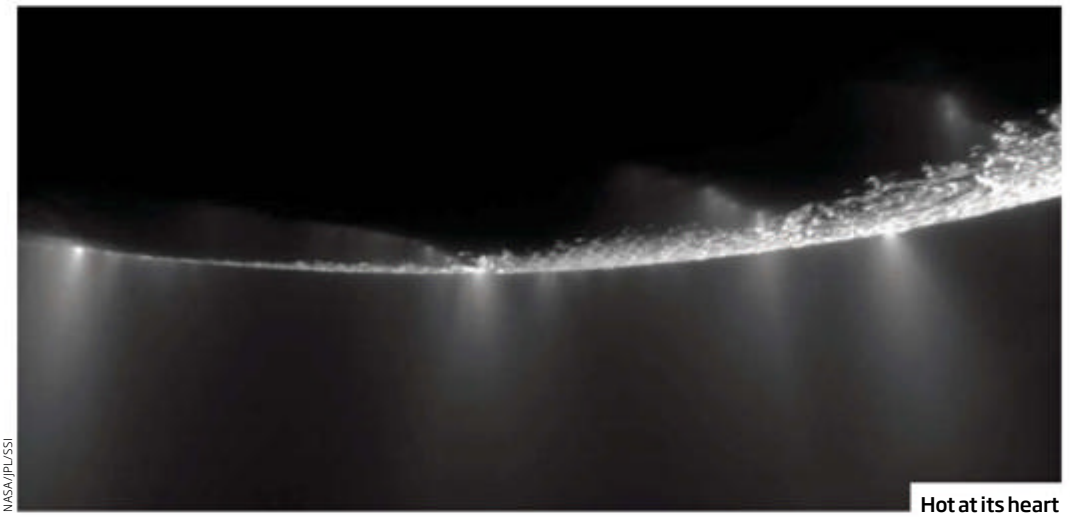
Meanwhile, Danti heads a programme funded by the US State Department, which is using satellite imagery and contacts in Syria and Iraq to monitor the destruction of cultural artefacts.

Danti is adamant that the illegal art market is fuelling the looting, in a vicious cycle of positive reinforcement. He is heartened by a recent UN resolution that will push member states to improve their ability to stem the illegal trade in antiquities from conflict zones in Iraq and Syria and punish the criminals.

Hanson agrees it's important to tackle the international markets, and encourage museums and private collectors to refrain from buying anything that looks like it's from Iraq or Syria at the minute. But unless the UN uses force to protect historical sites, Hanson is not sure what else the international community can do from a distance. "The region," she says, "is in a many ways losing its ancestors, its history." ■

POLARIS/EYEVINE

Under the hammer: other art is sold



NASA/JPL/SSI

Hot at its heart

Icy moon of Saturn has secret central heating

COLD shell, warm heart. Tiny sand grains gathered from Saturn's rings reveal that Enceladus, already famous for its impressive water jets, is hiding a warm ocean deep beneath its surface. The finding suggests this moon is the only known place besides Earth with ongoing hydrothermal activity, and boosts the chances of finding life below its cold exterior.

NASA's Cassini probe had already shown that Enceladus sprays plumes of dust and ice kilometres into the air. Combined with gravity data, this points to a subsurface ocean around 40 kilometres beneath the moon's south pole. Such an ocean could be a boon to the search for alien life, but anything living there would need a source of energy, because the sun is too far away to provide much warmth.

Now painstaking detective work by Hsiang-Wen Hsu of the University of Colorado, Boulder, and his colleagues has made a connection between sand grains picked up by Cassini over a decade ago and the moon's sea floor.

Cassini isn't able to scoop dust from Saturn's rings directly, but instead samples material accelerated away from the planet by its magnetic field. Hsu traced some of these grains to Saturn's E ring, which is thought to be created by Enceladus's plumes.

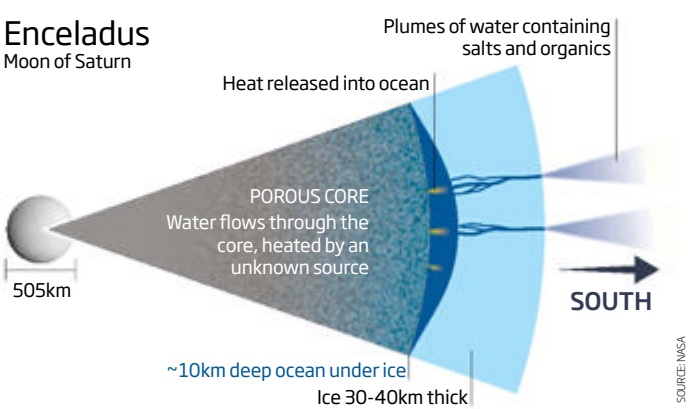
Cassini's Cosmic Dust Analyzer instrument revealed that the dust consists of silica particles between 4 and 16 nanometres across – like sand, but much smaller. That means the grains couldn't have formed from larger particles colliding within the rings, because then you would expect a greater range of sizes.

The team wondered if chemical reactions between rock and water on Enceladus's ocean floor could explain the finding. To investigate, they mixed water and silicon-rich rocks commonly found on asteroids and comets, then heated them under pressure for months to replicate conditions within Enceladus.

Out popped grains much like the ones Cassini had caught. What's more, they provided a measure of the temperature inside Enceladus: the right kind of particles only formed above 90 °C, suggesting the icy moon's interior must be at least that warm.

Hot springs

Saturn's moon Enceladus spouts plumes of water from an ocean covered by ice. Now there's evidence that the water is warmed by hydrothermal activity similar to that found on Earth – a good sign for finding life there



SOURCE: NASA

"All this independent evidence points in one direction, that means these particles most likely form from hydrothermal interactions within Enceladus," says Hsu (*Nature*, DOI: 10.1038/nature14262).

Hsu thinks the moon's entire core is probably porous and filled with warm water that diffuses up to the subsurface ocean. But the source of all this heat is still a mystery. Any heat left over from Enceladus's formation should have radiated away long ago. Tidal heating, generated by the squeeze of Saturn's gravity, wouldn't provide enough energy and chemical reactions or radioactive decay that could provide warmth should also have died out by now.

Enceladus may once have received a tidal heating boost from Saturn's other moons that we are now seeing effects of, but the details aren't clear, says Hsu.

There may be other reasons for the diminutive size of the grains seen by Cassini, says William McKinnon of Washington University in St Louis, but it's a promising find. "If there is a source of energy, that's one of the prerequisites for life," he says. "If the story that they've put together is true, then the implications for what's going on inside Enceladus are profound."

"It is a promising find. If there is a source of energy, that's one of the prerequisites for life"

Other icy moons are thought to harbour subsurface oceans, but the hydrothermal regions on Enceladus are particularly exciting because they closely match those found in the Atlantic, says Carolyn Porco, head of the Cassini imaging team. Bacteria thrive at such sites. "When we can draw a connection between an environment on Earth and an environment on Enceladus, that just ups the ante for the possibility we might find life," she says. **Jacob Aron** ■

INSIGHT Rape investigations

TED SOQUI/CORBIS

Easier collected than analysed

US mired in DNA testing backlog

Jessica Hamzelou

NO ONE knows the exact figures, but across the US, tens of thousands of rape test kits are thought to be lying around awaiting analysis. The country is finally starting to clear this backlog of DNA evidence from police investigations, some of which dates back decades. But simply spending more money on testing won't prevent history repeating itself. Poor training and attitudes on the part of investigators will also need tackling.

The use of DNA evidence in solving crimes took off in the 90s, when forensic scientists and many labs found themselves suddenly inundated with samples to test. In an effort to deal with the backlogs that built up, the federal government provided extra funding via the Debbie Smith Act in 2004. Even so, in 2009, a police storage facility in Detroit, Michigan, was found to be holding 11,000 untested rape kits. In 2013, the city of Memphis, Tennessee, admitted it had a backlog of 12,000.

It is unclear how many rapists may be walking free as a result, although since Houston, Texas, launched an effort to clear its backlog in 2013, 29 people have been charged. Last month, Houston officials announced that 850 DNA samples in the backlog – originally more than 6500 kits – had been matched to the FBI's DNA database, a possible method for spotting crimes such as serial rapes. Conversely, DNA testing also has the potential to exonerate innocent suspects.

Memphis has launched a $6.5 million project to have its backlogged evidence processed by a private lab. But funding was only ever part of the problem. A lack of communication between investigators and forensic scientists can also prove problematic, says Richard Pinchin at the Forensic Knowledge Partnership in Reigate, UK, who has advised US law enforcement agencies on how to tackle the unprocessed evidence.

In the UK, police forces send DNA evidence to private labs, which can be paid extra to turn around results within a day. To stick to budgets, investigators are more likely to select only the most relevant samples for analysis, says Pinchin. "That doesn't happen in the US," he says. US police forces mostly have their own labs, so tend to send all their samples for testing. This can lead to labs being overloaded with irrelevant material to process, creating backlogs.

"I remember when prosecutors used to ask us to test everything," says Mitch Morrissey, district attorney of Denver, Colorado. "That is ridiculous." He is retraining his investigators to be more selective in their DNA testing.

Another crucial aspect of police retraining has been to change investigators' attitudes towards people who report being raped. "The victim of rape is not always believed, but studies show that false accusations of rape are no greater than for any other crime," says Pinchin.

Studies suggest that victims are less likely to be believed if they have been drinking, for example, while local policing policies may require officers to be absolutely certain a rape has taken place before sending a test kit for analysis. Both scenarios could help explain why so many DNA samples are collected, only to end up sitting in a warehouse. ■

Tag valuables with a plastic fingerprint

WHO says only humans should have fingerprints? A technique for generating artificial ones could see banknotes, jewellery and other valuables tagged with a unique pattern to fight counterfeiters.

Wook Park of Kyung Hee University in Seoul, South Korea, and his colleagues created fake fingerprints by mixing two kinds of plastic to make discs that were 0.4 millimetres across. They then coated the discs with a thin layer of silica and dried them out, shrinking the plastic core and making the discs wrinkle like fingerprints (*Advanced Materials*, doi.org/f25p5s).

To test their uniqueness, the team created thousands of patterned discs and analysed them using standard fingerprint recognition algorithms. The minutiae – the ridges used to identify fingerprints – on the fakes were similar to human prints. In fact, the fakes had more variety, because human fingerprints are likely to orient themselves to our fingertips.

The team also experimented with prints shaped like letters, squares and stars to add variety. Theoretically, their method can produce 10^{135} unique patterns – far more than the number of atoms in the universe.

Next they applied fake fingerprints to a passport, a ring and a watch. The prints are just large enough to be visible to the human eye, but small enough to be unobtrusive. Using a portable microscope attached to an iPhone camera, they took a picture of the fingerprints and could see the ridges, although the resolution was too low to uniquely identify them.

"Theoretically, they can produce more fingerprints than the number of atoms in the universe"

Arun Ross of Michigan State University in East Lansing says fake fingerprints might someday replace your own, if they can be securely linked to an individual. Right now, if your fingerprints are stolen there is no way to revoke them, like you would a compromised password. "There could be some value in considering this for creating cancellable biometrics," he says. Jacob Aron ■

The oldest ancestor we never knew we had

IS IT the oldest human fossil? Scientists were careful not to call it that – "human" means different things to different people – but it does appear to be the oldest known fossil yet from our own genus, *Homo*.

Unearthed in Ethiopia, the broken jaw with greying teeth suggests our lineage existed up to 400,000 years earlier than previously thought. The fragment dates from around 2.8 million years ago.

Since it shows traits from both the apelike *Australopithecus* and from *Homo*, it pinpoints the time when our ancestors began their transition to becoming the big-brained conqueror of the world, says Brian Villmoare from the University of Nevada, Las Vegas, whose team made the find (*Science*, doi.org/2mq).

Geological evidence, in a separate study led by Erin DiMaggio from Pennsylvania State University, shows that the jaw's owner lived just after a major climate shift in the region: forests and waterways rapidly gave way to arid savannah, leaving only the occasional crocodile-filled lake (*Science*, doi.org/2mr). Except for the sabre-toothed big cat that roamed these parts, the environment ended up looking much like it does today.

The pressure to adapt to this new world probably jump-started our evolution, according to Villmoare. It's likely that the emerging *Homo* species began eating more meat and using tools, a change reflected in a more delicate jaw specimen that Villmoare's team unearthed in 2013. After all, if you had a nice sharp stone to cut with, there was no need for a mouth built to tear food to shreds.

KAYE REED

Jaw-dropping stuff

Pierre Chardin from France's National Institute of Health and Medical Research is not convinced. He says that a single fossil can be misleading when identifying a species, and that a full skull is needed for us to be confident about who it belonged to.

But another study, by Fred Spoor from University College London and colleagues, appears to strengthen the fossil's *Homo* credentials. The team used a medical scanner to image a badly preserved *Homo habilis* skull and jaw from 1.8 million years ago. This allowed them to reconstruct it and compare it with other ancient *Homo* fossils. They conclude that the common ancestor of *Homo* must have emerged much earlier than thought (*Nature*, doi.org/2ms).

Taken together, the two results connect the dots across a huge swathe of human history, says Spoor. Starting with the divergence of *Homo* from its apelike cousins, there is now a clear evolutionary pathway to its relatives a million years down the road. Given that this period of 2 to 3 million years ago has long been an archaeological blind spot, this insight is a big deal, he says. Jan Piotrowski ■

PHIL DEGGINGER/ALAMY

Shape of things to come

Roving alloy could drive future robots

Michael Slezak

HASTA la vista, baby. A real-life T-1000, the shape-shifting liquid-metal robot from *Terminator 2*, is a step closer, thanks to a self-powered liquid metal motor.

The device is surprisingly simple: just a drop of metal alloy made mostly of gallium – which is liquid at just under 30 °C – with some indium and tin mixed in. When placed in a solution of sodium hydroxide, or even brine, and kept in contact with a flake of aluminium for "fuel", it moves around for about an hour. It can travel in a straight line, run around the outside of a circular dish, or squeeze through complex shapes.

The machine looks rather intelligent, says Jing Liu from Tsinghua University in Beijing, China, and it can "deform itself according to the space it voyages in, just like [the] Terminator does from the science-fiction film", he says. "These unusual behaviours perfectly resemble the living organisms in nature." They could even raise questions about the definition of life, he says.

When they first saw the drop move, Liu and colleagues weren't sure how it was able to do so. Experiments revealed two mechanisms at play. Some of the thrust stems from a charge imbalance across the drop, which in turn creates a pressure differential between the front and the back that pushes it forward. The aluminium also reacts with the sodium hydroxide, releasing hydrogen bubbles which drive the drop even faster (*Advanced Materials*, doi.org/f26cb6).

"It looks rather intelligent and can deform itself according to the space it is in, just like the Terminator"

Other researchers have shown that a stationary gallium drop can act as a pump when in an electric field. Liu followed up this idea and showed that if their self-powered motor is held still, it too becomes a pump, shifting about 50 millilitres of water every second. "It's the first ever self-powered pump," he says. The team says that it could have immediate applications for moving liquid through a cooling device without the need for an external power source.

The work is part of a long-term effort to create intelligent robots that are non-rigid and so can be reshaped on the fly, a bit like the fictional T-1000. Liu says a robot based on their device could soon be used to monitor the environment or deliver materials within pipes and even blood vessels.

Last year both Liu's group and one led by Michael Dickey at North Carolina State University in Raleigh showed that the gallium alloy forms complex shapes in response to an applied electrical current. When the current is turned off, it returns to the simple drop shape. Liu says these two methods could be used together to change the drop's velocity, or to coordinate a swarm of independent drops.

Taro Toyota of the University of Tokyo in Japan says the invention could help convert chemical energy to mechanical energy in a future liquid robot. "Such liquid robots will be a seed of artificial life seen in some movies," he says. "I would raise *Flubber* instead of *Terminator 2*." ■

HIV's hiding places revealed by simple scan

IT'S LIKE using heat cameras to catch criminals on the run, except that HIV is the target. A novel scanning technique is enabling researchers to pinpoint where in the body HIV is lurking.

Today's potent drugs can eradicate HIV from the blood, but the virus returns when people stop treatment. This suggests that it survives elsewhere in the body – possibly by replicating very slowly or lying dormant inside immune cells at "sanctuary sites".

One strategy for eradicating HIV completely might be to "wake up" the hiding virus and then kill it, but little is known about which sanctuary sites might be the most important, what the virus is doing there and whether existing drugs can reach these sites.

François Villinger of Emory University in Atlanta, Georgia, and his colleagues wondered whether PET scanning, which is used to show the spread of cancer, could also reveal the location of HIV. This idea was prompted by the discovery of an antibody that binds strongly to a protein called gp120, which is made by the monkey version of HIV.

To test the idea, the team injected a radioactive version of the antibody into three infected monkeys that were being treated with antiviral drugs. PET scanning, which detects radioactivity within the body, uncovered gp120 in a range of sites including the nose, lungs, gut, genitals and lymph nodes in the armpits and groin (*Nature Methods*, doi.org/2qx). The antibody could not get into the brain, however, which is thought to be another sanctuary site.

Post-mortem tests on the monkeys confirmed that the virus was present in immune cells from the areas identified by the scan.

This is the first study to visualise viral reservoirs, says Alan Winston of Imperial College London. "This could really help with the research for a functional cure." Clare Wilson ■

GET INSIDE YOUR OWN HEAD

The Human Brain uncovers everything you need to know about the most complex object in the known universe

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NewScientist

DAVID ELLIFRIT/CENTER FOR WHALE RESEARCH

Orca oracles lead pods through troubled waters

CALL them oracles of the orca world. Female killer whales may live beyond the menopause so that they can use their experience and wisdom to ensure the survival of the entire pod, especially during food shortages.

Female orcas often live into their 90s, even though they typically stop breeding at 40. As far as we know, the only other species to go through a menopause and live so long without reproducing are humans and short-finned pilot whales. So why orcas?

To try and figure it out, Darren Croft of the University of Exeter, UK, and his team analysed 750 hours of video of more than 100 orcas filmed in the coastal Pacific waters off British Columbia and Washington since 1976.

They found that post-menopausal females were 32 per cent more likely to lead the group than non-menopausal adult females and 57 per cent more likely than adult males. They were also more likely to be in charge in years when their staple food – chinook salmon – was in short supply (*Current Biology*, doi.org/2mx).

"Post-menopausal orca females act as repositories for important knowledge. They essentially store important survival information," says Croft. "Anyone who fishes for migratory trout or salmon will tell you that timing is key, that the fish return in particular cycles of tides and times of the year. Post-menopausal females probably get to know where to look and when."

Too much praise makes Jack a vain boy

YOU'RE so vain, you probably had overpraising parents. One of the first extended studies of childhood narcissism suggests that heaping praise on your kids could make them more prone to being selfish and vain.

There are two competing theories of how narcissism can arise in children. One is that they may be compensating for having cold, unloving parents. The other is that their parents praise them too much, giving them an inflated sense of self-worth.

Eddie Brummelman at the University of Amsterdam in the Netherlands and his colleagues tested these ideas by studying 565 children aged 7 to 12, a period in which narcissistic traits can emerge. Over 18 months, the children and their parents answered regular questionnaires designed to measure narcissistic traits and parental behaviour.

The team found no correlation between parental coldness and narcissism in the children, but did find a clear link between how much parents praised their children and how narcissistic the kids were six months later (*PNAS*, DOI: 10.1073/pnas.1420870112).

However, the effect was small, so other factors may also make people self-centred – perhaps genetics, says Brummelman.

Moths remember their first time

SOMETIMES it pays to be sentimental. Where African cotton leafworm moths mates for the first time helps decide the location of future liaisons, and where they lay their eggs.

Although the moths have a large number of host plants, they innately prefer some, like cotton over cabbage. But Magali Proffit of the Swedish University of Agricultural Sciences in Alnarp and her colleagues found that if the first time the moths mated was on cabbage, they showed an increased preference for it. And mating had to be involved: moths didn't just favour plants they were familiar with, even those sprayed with a sex pheromone (*Ecology Letters*, doi.org/2m4).

Such behaviour could one day result in groups of the moth diverging into different specialist species, says Peter Roessingh of the University of Amsterdam, the Netherlands.

Messed up mirrors manipulate light

FUNHOUSE mirrors just got a lot wackier. Reflective surfaces built using artificial materials could bounce certain kinds of light at strange angles, or make a mirror that turns into a window.

A normal mirror reflects light back at the same angle it hits, but this is not true of "metamirrors" – so called because they are made of metamaterials, whose complex structure lets them manipulate light. The only one made so far sends face-on microwaves back at a 45 degree angle (*Physical Review Letters*, doi.org/2pn).

Because metamirrors are tuned to work at a certain wavelength, and are transparent to all others, a surface could be made that is, say, mirrored under red light but see-through for other colours.

Need a shield? I'll fold one for you

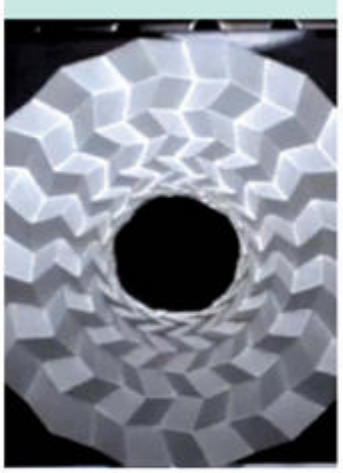
A SUIT of armour made from paper sounds about as useful as a chocolate teapot, but it all depends on how you build it. Bin Liu of the University of California, Merced, and his colleagues have created a precision-folded origami shield that can keep anything inside it safe.

The shield is a paper doughnut with a hole in the centre, and has been scored with an exact pattern of perforation lines by a laser. The pattern consists of smaller and smaller concentric circles, with each circular strip further divided into triangles. The triangles in adjacent strips lean in opposite directions, creating a network of zigzags from the rim to the centre.

Apply pressure to the edge of the shield and it begins to fold up along these zigzags. But because the folds' sizes shrink incrementally, the hole in the centre never changes size, protecting anything inside.

It's not the first time researchers have been inspired by origami – NASA is investigating folded solar panels to pack large power arrays on board rockets, for instance.

Liu, who presented the shields at the American Physical Society meeting in San Antonio, Texas, on 2 March, says because the protection doesn't rely on the strength of the material, it should find a number of uses. "We can bring robust structure into light and soft materials."



BIN LIU LAB

Fast star first fled from a supernova, now the galaxy

IF A thermonuclear explosion went off next door, you'd run away too. The fastest known free-flying star in the galaxy is hightailing it out of here after its sibling exploded as a massive supernova.

Known as US 708, the star appears to be the remnant of a red giant that was stripped of all its hydrogen. Stephan Geier of the European Southern Observatory in Garching, Germany, and his colleagues measured the star's speed relative to the centre of the galaxy, and found it was a little under 1200 kilometres a second.

All the other stars found so far that are travelling fast enough to escape the Milky Way are moving slower than US 708, and are more similar in mass and temperature to our sun. Such hypervelocity stars were probably twins that strayed too close to the supermassive black hole at the centre of our galaxy. Then one star got stuck orbiting the black hole, while the other was cast out.

But that explanation doesn't work for US 708: something must have stolen its hydrogen before it sped up. This could only happen if it was very close to another star – so close that even a black hole couldn't tear them apart.

"The only way to get rid of the companion is a thermonuclear supernova," Geier says. US 708's sibling may have been a white dwarf star that stole its hydrogen before exploding in a massive supernova (*Science*, doi.org/2m2).

It was actually the breaking of that bond that accelerated US 708, not the explosion itself – a bit like when you hold hands with someone, spin around and let go.

Confident voice? We decide in a second

WATCH what you say, or rather, how you say it. People judge whether you believe in what you say after just 0.2 seconds.

Xiaoming Jiang and Marc Pell of McGill University in Montreal, Canada, made this discovery by recording brain activity as volunteers listened to recorded statements that had been previously rated for how confident they sounded.

A specific type of brain activity that relates to increased processing of information appeared 200 milliseconds after the start of the clip, whatever its confidence level. However, more confident speech produced higher activity than unconfident speech.

This suggests listeners' brains may prefer confident statements, assigning them more attention and processing them more quickly, says Jiang.

So what's the key to sounding confident? It's hard to say – confident voices were acoustically similar to nearly confident and neutral voices. Unconfident statements tended to be higher in pitch and slower than all others, and their pitch also tended to rise towards the end (*Cortex*, doi.org/2m6).

PREMAPHOTOS/ALAMY

White tache helps spider to lure prey

IT'S official: facial hair is attractive. The brown huntsman (*Heteropoda venatoria*) sports a fine white moustache that it uses to lure in food at night. The spider's 'tache-like bristles, located below its eyes, form a whitish stripe that reflects light differently from the rest of the body, and nocturnal insects such as moths seem to head straight for it.

I-Min Tso and his team from Tunghai University in Taichung, Taiwan, conducted field experiments with real and dummy spiders to test whether the moustache was a lure. They used infrared cameras to record and compare the numbers of prey approaching spiders with a moustache and those who had theirs shaved off. The shaved spiders attracted significantly fewer prey (*Animal Behaviour*, doi.org/2m3). "It is highly possible that the moths have mistakenly regarded the white coloration as a nocturnal blooming flower during their foraging at night," says Tso.

Other arachnids have a similar trick. Recent studies have shown that the brightly coloured bodies of spiders such as *Nephila pilipes* attract unwitting prey to their webs.

Caught before the act

Police in the US and Europe are increasingly using "pre-crime" software to prevent offences from happening, finds **Chris Baraniuk**

THEY always choose the line at the bank farthest from CCTV – that's how the Felony Lane Gang got its name. With crimes committed in 34 states, they've withdrawn millions of dollars from banks using cheques and credit cards stolen from cars. A handful of individuals connected to the group have been arrested, but the ringleaders have remained at large for years. Can crime-predicting software finally stop them in their tracks?

That's the hope of police in the US, who have begun using advanced software to analyse crime data in conjunction with emails, text messages, chat files and CCTV recordings acquired by law enforcement. The system, developed by Wynyard, a firm based in Auckland, New Zealand, could even look at social media in real time in an attempt to predict where the gang might strike next.

"We're trying to get to the source of the mastermind behind the criminal activity, that's why we're setting up a database so everybody can provide the necessary information and help us get higher up the chain," says Craig Blanton of the Marion County Sheriff's Office in Indiana. Because Felony Lane Gang members move from state to state to stay one step ahead, the centralised database is primed to aggregate historical information on the group and search for patterns in their movements, Blanton says.

"We know where they've been, where they are currently and where they may go in the future," he says. "I think had we not taken on this challenge, we along with the other 110 impacted agencies would be doing our own thing without better knowledge of how this group operates."

It's not the only system that police forces have at their disposal. PredPol, which was developed by mathematician George Mohler at Santa Clara University in California, has been widely adopted in the US and the UK. The software analyses recorded crimes based on date, place and category of offence. It then generates daily suggestions for locations that should be patrolled by officers, depending on where it calculates criminal activity is most likely to occur.

"We're trying to get to the source of the mastermind behind the Felony Lane Gang's criminal activity"

Kent Police in the UK have been using PredPol for two years. A few months ago, officers were given a patrol location by the system and initially thought it strange – it wasn't in one of the areas most commonly affected by street crime. They visited the location anyway and discovered a distressed woman and a child in public. The woman had been beaten up and the child sexually assaulted.

"The officers managed to take care of them and also managed to apprehend the offender, who was a known and wanted suspect," says Mark Johnson, head of analysis at Kent police.

He says that when the statistical data for the area in question was analysed, officers realised that although it was not as prone to crime as other areas, similar offences had been recorded there in the past. The software did not predict a specific crime, but it predicted that something violent was likely to take place – and it was right.

Targeting which areas to patrol has had a significant effect. Johnson says that PredPol is one

EYEVINE/STOCKIMO/ALAMY

of the reasons why the annual number of recorded crimes in Kent has fallen from 140,000 to 100,000 since its implementation.

Part of the enthusiasm for this technology has come from officers burdened by tightening budgets, especially in the US, says David Roberts at the International Association of Chiefs of Police. "There's been real pressure on law enforcement agencies to work smarter, to do more with less and be much more proactive in targeting their scarce resources," he says.

Burglary here

David Wall, professor of criminology at the University of Durham, UK, thinks statistical technology can be highly beneficial but he warns that not all crimes can be predicted – yet.

Owner or prowler?

"Anomalies can happen anywhere and these are not necessarily related to social circumstances, they tend to be related to circumstances that are unveiled at a particular moment in time," he says. "The classic one is a domestic argument that gets out of hand and turns violent. It's very hard to predict that."

Predictive policing software packages are being adopted across mainland Europe, too. In Germany, researchers at the Institute for Pattern-based Prediction Techniques (IfmPt) in Oberhausen have developed a system for tackling burglaries. Precobs works by analysing data on the location, approximate date, modus operandi and stolen items from robberies going back up to 10 years.

Based on this information, Precobs then predicts where burglaries are likely to happen next. This is tightly defined, within a radius of about 250 metres, and a predicted time window for the crime of between 24 hours and 7 days. Officers are then advised to focus their resources in a flagged area.

Precobs has been trialled in the Swiss cantons of Basel-Landschaft, Zurich and Aargau as well as in a number of German cities including Munich and Nuremberg. Michael Schweer, head of analysis at IfmPt, says that the accuracy of predictions so far is about 80 to 85 per cent – meaning that burglaries happened in most of the areas the software predicted.

"The next step is to have an app that delivers crime predictions to police on their smartphones"

This allowed police to conduct more targeted investigations and Schweer says that in Zurich the number of people arrested in connection with such crimes approximately doubled over the past 18 months. What's more, in areas policed with the aid of the system, the overall number of burglaries has fallen as much as 35 per cent, thanks to more arrests and a more effective police presence on the streets.

"All our customers on pilot projects [have said they] will take it forward to regular use," says Schweer. He adds that at the end of the month, IfmPt will announce a personal app for police officers that will deliver a crime prediction to their smartphones or tablets. "The next step with this kind of instrument is to have the data implemented right on the spot," he says.

In France, meanwhile, a system provided by Sûreté Globale has enjoyed success for several years targeting a variety of crimes, not just burglaries. Spokesman Sébastien Delestre says that police in Paris tested the approach to crack down on joyriding on New Year's Eve five years ago. They arrested twice as many people as the year before, he says. The software is now being used in Lyon, Lille and several smaller towns.

Sending police to areas where crime hasn't yet occurred may sound intrusive, and raises the spectre of a police force following conclusions based on data that could keep pointing them to poor or minority communities. But it might be an improvement compared with recent high-profile cases of police bias, such as that reported last week after an investigation into the shooting of Michael Brown by a police officer in Ferguson, Missouri, last year. Predictive policing may be better both for law enforcement officers and the citizens they are charged with protecting.

"There's no question that you can have biases within data but there are some ways to detect that bias mathematically," says John Morgan, former director of the Office of Science and Technology at the US National Institute of Justice. "These tools allow officers to make real decisions with, in my view, much less bias than they otherwise might." ■

ONE PER CENT

HYPERLOOP TRANSPORTATION TECHNOLOGIES

Hyperloop evolves

California, get ready to Hyperloop. The near-supersonic train proposed by SpaceX founder Elon Musk could get even faster. Casey Handmer at the California Institute of Technology in Pasadena found he could shave 139 seconds off the proposed travel time by using genetic algorithms to calculate the optimum route between Los Angeles and San Francisco. Last month, Hyperloop Transportation Technologies announced plans to build 8 kilometres of test track.

"If you can print a liver or a kidney, god dang it, you're going to be able to print a whole freaking person"

Musician **Will.i.am** predicts the future of 3D printing in *The Guardian*

'I got home safe' app

Have you ever forgotten to text a friend to say you got home safe after a night out? A new app called pingWHEN tracks your progress home and sends a text message to a chosen friend when you arrive at your preset destination. If you deviate from the most likely route or take too long to arrive, then the app can send an alert to your chosen contact, along with your exact location.

Casting the net for jurors

Lawyers are asking for online help with cases, finds **Aviva Rutkin**

I HAVE only a few pages of evidence with which to decide the fate of a maintenance man from Texas. While at work trying to untangle a spool of wire on a crane, his right hand was caught and severed when the line pulled taut. He sued for negligence, and I am leafing through his lawyer's court strategy trying to decide who is to blame and what damages are due.

This is the work of an online juror. For 20 minutes to an hour of work and up to $1 per minute in pay, ordinary people can offer their opinions on real cases to the attorneys who are working on them. These amateur assessments, crowdsourced and interpreted by online services, give lawyers insight into how an actual jury might rule long before anyone steps into the courtroom.

Mock juries are nothing new, but they are typically performed in person. Lawyers often bring volunteers into a courtroom to observe a fake trial and reach a verdict. But these run-throughs can cost tens of thousands of dollars, all for a single jury's opinion. Adrienne LeFevre of the service OnlineVerdict, based in Chicago, says online mock trials allow attorneys to pick the brains of dozens or even hundreds of mock jurors.

"If you hear over and over again what's bothering the jurors about the case, you'll know what your weakness is," says LeFevre. "It's a small investment for a great amount of information."

The cases that OnlineVerdict tests run the gamut from civil litigation to criminal trials to patent disputes. For each, the service develops a questionnaire that jurors fill out to say whether they side with the plaintiff or defendant and to give their responses to different legal arguments. The questions are then sent out, along with a short summary of each side's position, to a sample of volunteers in the site's database who align with the expected demographics of the real jury in a case.

"For up to $1 per minute in pay, ordinary people can offer their opinions on real cases"

Some lawyers will run their arguments by as many as 500 fake jurors, says Chris Bagby at eJury, an online jury service based in Bend, Oregon. Such huge amounts of data allow attorneys to see how rulings differ according to jurors' age, race or gender. Lawyers can also examine whether people were moved by a particular piece of evidence, which in turn they might choose to focus on in the trial. In the case of the Texas maintenance man, 92 per cent of the 50 online jurors voted in favour of awarding him damages. The case ultimately settled out of court last year.

"Knowing the community you're speaking to, what interests them and what they care about means you're able to tell your client's story in a language that the jury would be receptive to," says Christopher Land, general counsel at Woods Hole Oceanographic Institute in Massachusetts, who has used online jury services.

Online jury work is part of the booming internet "gig economy", in which people sign up to perform small tasks or answer research questions for a few pennies. To join a site such as OnlineVerdict or eJury, a prospective juror only needs to prove that they are a US citizen and eligible to vote, as well as promise to hold the details of the case in strict confidence. Online jury work is not poised to replace anyone's day job, however: cases only go out to the few volunteers who match the right demographic mix, meaning that a person can go months between assignments.

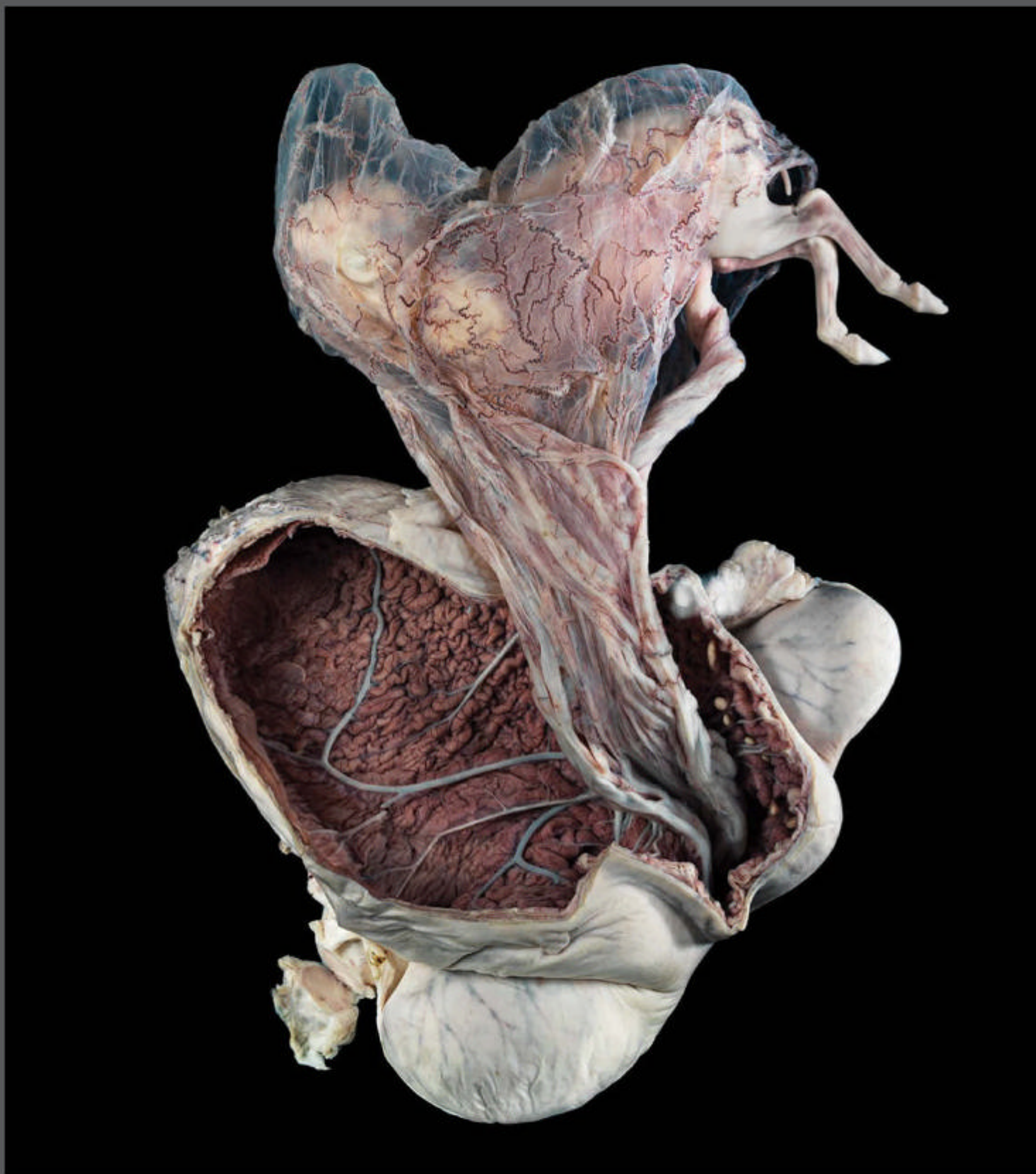
Rich Matthews, a trial consultant in San Francisco, is sceptical that these sites can replace traditional mock jury research. By soliciting opinions virtually, he says, all of the subtle non-verbal cues that go into a real trial are lost. The jurors miss out on the dynamic experience of deliberating with one another, and the lawyers do not pick up on the intensity or the tone of the jurors' opinions.

Still, Bagby says the simulated juries often anticipate the result of a case, making them useful tools for attorneys who are planning their legal strategies.

"What happens at the courthouse is very close to what happens with eJury," he says. ■

SUPERSTOCK

Mock trials are moving online



My little pony

YOU won't have seen a New Forest pony quite like this before. The one shown here (main image) was never actually born. You can see its hairless, fetal legs kicking from the uterus of its mother.

It is part of the collection at the Royal Veterinary College in London, photographed by Michael Frank through the pots and vessels in which the specimens are held. To finish the images, he digitally cleaned up reflections and scratches on the pots afterwards.

Did this project to document the college's collection make him feel queasy at all? "Even if some pots are visually challenging, I must admit it never turned my stomach because I could always see the beauty within," says Frank, who was enchanted by the college's museum. "It was like an open window on creation, and I guess it goes back to the child's fascination to see how things are made inside."

The image of the pony, and the one next to it (right, top) showing the reticulum of a goat, have been shortlisted in the Wellcome Image Awards 2015 (bit.ly/imageawards2015). Found in ruminants (cattle, goats and sheep), the reticulum is a stomach chamber: the beautiful honeycomb pattern is characteristic of this organ. At the top of this image, the oesophagus is also visible. The bottom-right picture is the uterus of a cat that was pregnant with four kittens. Rowan Hooper

Photographer
Michael Frank/Wellcome Images
mickfrank.com

The plain truth

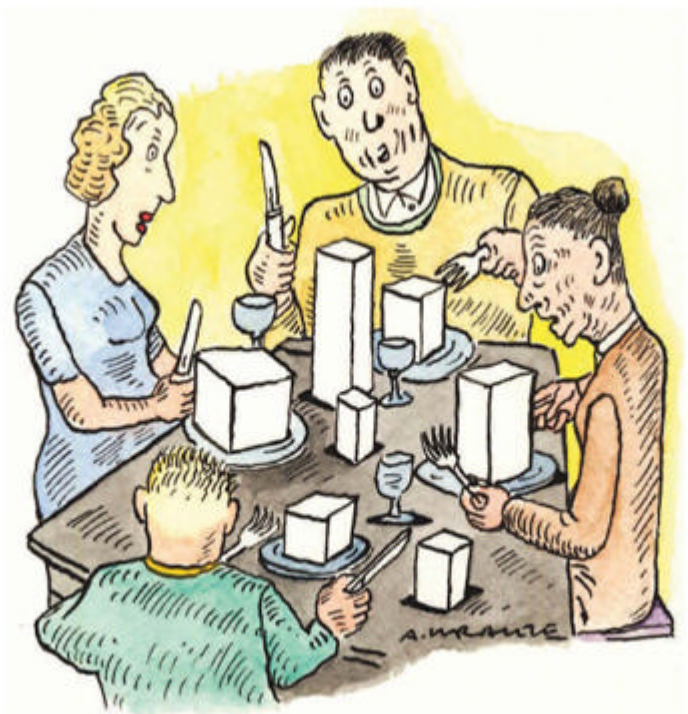
The tobacco industry claims uniform packets are just the start and the food industry will be next. Not so, says **Marion Nestle**

ANTI-SMOKING advocates are eagerly awaiting a vote on uniform packaging for cigarettes in the UK. That plain wrappers will undoubtedly further reduce smoking, especially among young people, is best confirmed by the tobacco industry's vast opposition to this government proposal and positive evidence from Australia, the first country to adopt it.

Along with lobbying and appeals to the World Trade Organization, the tobacco industry, when under attack, inevitably wheels out well-worn arguments about the nanny state, personal freedom, lack of scientific substantiation, and losses in jobs and tax revenues.

So to perk up its tired and thoroughly discredited campaign, the tobacco folks have added a new argument. Requiring plain wrappers on cigarettes, they say, is a slippery slope: next will be alcohol, sugary drinks and fast food. This argument immediately raises questions. Is it serious or just a red herring? Should the public health community lobby for plain wrappers to promote healthier food choices, or just dismiss it as another tobacco industry scare tactic?

Let me state from the outset that foods cannot be subject to the same level of regulatory intervention as cigarettes. The public health objective for tobacco is to end its use. So for cigarettes the rationale for plain wrappers is well established. Company logos, attractive images, descriptive statements, package colours and key words all promote purchases. Plain wrappers discourage buying, especially along with other measures such as bans on advertising, smoke-free policies, taxes and health warnings.



Australia's pioneering law specified precise details of pack design, warning images and statements. The result: cigarette brands all look much alike. Most reports say plain packaging boosts negative perceptions of cigarettes among smokers and increases their desire to quit. Australia expects plain packaging to further reduce its smoking rate, which, at 12.8 per cent, is already among the world's lowest. Along with the UK, New Zealand and Ireland are well on the way to adding plain packaging to their anti-smoking arsenal. More nations are considering it.

Which is all bad news for the tobacco industry. So it ramps up the slippery slope argument, hoping the food industry will support its fight against plain wrappers. It cites examples such as the regulation of infant formula in South Africa, where pictures of babies on labels are forbidden; that's a big problem for the Gerber food brand – Gerber's company logo is a smiling baby.

But those peddling the slippery slope idea ignore the fact that the health message for tobacco is simple: stop smoking. But beyond tobacco, it is more complex. For alcohol it is a little more nuanced: drink moderately, if at all. For food it is much more nuanced. Food is not optional; we must eat to live. Nutritional quality varies widely. Foods are spread across a spectrum from unhealthy to healthy, from soft drinks (no nutrients) to carrots or fish (many nutrients). Most fall somewhere in between. What's more, an occasional soft drink is fine; daily guzzling is not. So the advice is to choose the healthy and avoid or eat less junk, both in the context of calorie intake and expenditure.

"Plain packaging boosts negative perceptions of cigarettes among smokers and ups the desire to quit"

Is there any evidence that plain packaging for unhealthy foods would reduce demand? Research has focused on marketing's effect on children's food preferences, demands and consumption. Brands and packages sell foods and drinks, and even very young children recognise and desire popular brands. When researchers compare the responses of children to the same foods wrapped in plain paper or in wrappers with company logos, bright colours or cartoon characters, kids invariably prefer the more exciting packaging.

But the problem is deciding which foods and beverages might call for plain wrappers. For anything but soft drinks and confectionery, the decisions look too vexing. Rather than having to deal with such difficulties, health advocates prefer to focus on interventions that are easier to

justify – scientifically and politically.

We know that some regulations and market interventions – analogous to, if not the same as those aimed at smoking cessation – are essential for reducing the damage from harmful products. If not plain packaging, then what? Studies suggest small benefits from a long list of interventions such as taxes, caps on portion size, front-of-package traffic-light labels, nutrition standards for school meals, advertising restrictions, and elimination of toys from fast food meals and cartoons from packaging. Rather than dealing with the impossible politics of plain wrappers on foods, health advocates increasingly favour warning labels.

These first appeared on cigarette packs in the 1960s and have been considered for food products since the early 1990s. Heart disease researchers suggested that foods high in calories and fat should display labels such as: "The fat content of this food may contribute to heart disease." More recently, health advocates in California and New York proposed warning labels on sugary drinks. The Ontario Medical Association takes a similar view: "To stop the obesity crisis, governments must apply the lessons learned from successful anti-tobacco campaigns." It has mocked up examples of warnings on foods.

Although no warning label law has passed so far, such messages are the logical next step in promoting healthy food choices, in the same way that plain wrappers are the next logical step for all cigarette packages. Health advocates should recognise the slippery slope argument for the typical tobacco ploy that it is. ■

Marion Nestle is the author of *Food Politics* and *What to Eat* and is the Paulette Goddard professor of nutrition, food studies, and public health at New York University

ONE MINUTE INTERVIEW

Life in a zombie apocalypse

How would you behave in a real-life disaster? I'm exploring how we do it in virtual worlds to find out, says **Matthieu Guitton**

PROFILE

Matthieu Guitton is an associate professor in the faculty of medicine at Laval University in Quebec City, Canada. He explores human behaviour and social dynamics in virtual worlds, and develops interfaces between minds and artificial systems

Why use online games to study our responses to catastrophic events?

You can't go into the middle of a real-life disaster area and ask people: "What are you doing? How do you feel?" They're too busy trying to survive. And in the aftermath of an event, it's difficult to ask survivors questions like: "Did you betray other people or let them die so that you could survive?" Ethical considerations aside, you can't be sure they would tell you the truth. Immersive virtual worlds provide ways to test human behaviour in controlled "life-threatening" situations.

What sort of games are you looking at?

I've been studying how people behave in *DayZ*, an immersive game with over a million users. It's a survival game set in a post-apocalyptic, zombie-infested country. Players have to find food, weapons or medical supplies while their lives are under constant threat from zombies or hostile players. Unlike in a lot of games, when your character dies in *DayZ*, it stays dead. If you want to continue playing, you have to start from scratch in a random place with none of your previously gathered gear. When you've invested time in your character, you don't want it to die, so you don't mess around – just like in a real situation.

How do you examine players' behaviour and feelings?

We go into the game and look at what they're doing in real time, interview them, or read about their experiences in *DayZ*'s forums. Betrayal and selfish behaviour are common. Players sometimes express guilt, or ask on forums whether their actions were justified or ethical, leading to many conversations about ethics and behavioural norms. Say someone shoots their friend in the leg so that a zombie will attack them, giving the shooter the chance to run away. Later they may feel guilty, and if they spot a new person in the game they might give them food or weapons, even if this leaves them with less for themselves.

Can "virtual anthropology" really yield broad insights into our behaviour?

I think so. It's not the case that you have the real world on one hand, and virtual communities disconnected from any real-life concerns on the other. When I was studying virtual communities in *Second Life*, I interviewed a girl who'd just broken up with her virtual boyfriend. She asked me: "If it's all a game, why are my tears real?" People invest a lot emotionally in these games, so it makes sense to study them. It's not like you're playing *Super Mario* and just killing mushrooms.

How would you rate your own chances, come the zombie apocalypse?

I would like to think I'd be a hero, but I'd probably run like everyone else and try to save my own life. But that's why studying behaviour using virtual spaces is important: by understanding how people react to catastrophes, we can optimise ways of educating them about appropriate reactions. In Japan, people are trained from childhood on how to react to earthquakes, and there are fewer casualties as a result.

Interview by Linda Geddes

How we hounded out the Neanderthals

Soon after humans arrived in Europe, Neanderthals died out. Was this because we had "living weapons", asks **Pat Shipman**

HUMANS are natural invaders, the mammalian equivalent of Burmese pythons, cane toads and Asian carp. Our species came from Africa and invaded Europe about 50,000 years ago. Perhaps surprisingly, this invasiveness may explain why we have outlasted our last close relatives, Neanderthals, by tens of thousands of years. I believe that the key to our success as invaders lies in our partnership with a weapon with a wagging tail: the domestic dog.

When early modern humans first entered Europe, Neanderthals had been living there for roughly 250,000 years. They knew the terrain and ecosystem intimately. They shared many of our physical and behavioural traits, such as large brains, specialised abilities for making tools and fire, and methods for hunting the same large game. Genetically, Neanderthals were so much like us that we interbred, albeit rarely. Yet the evidence is very clear that we thrived during the period of overlap,while Neanderthals went extinct. Why?

Climate instability has been a favourite candidate. Severe fluctuations from warmer and wetter to colder and drier, and back again, started about 45,000 years ago. Until recently, Neanderthal sites appeared to show a pattern of progressive retreat to more southerly, milder locations, ending with their extinction about 27,000 years ago. However, improvements in radiocarbon dating have dramatically undercut this interpretation.

All well-dated Neanderthal sites have been found to be at least 39,000 years old and no southerly shift through time is evident. Besides, we faced the vacillating climate at the same time as the Neanderthals and they had survived similar cold periods before our arrival. Some new factors were at work.

Our presence was one element. Did we force Neanderthals into extinction? Yes, but not through violence or killing – once a preferred hypothesis. We were simply better at hunting than they were.

A model for understanding how one invasive predator might outcompete a similar rival comes from the reintroduction of wolves to Yellowstone National Park in the US. Though wolves were integral to that ecosystem for millennia, they were wiped out there by settlers by about 1920. The effects of removing the wolf were striking. Coyotes formed larger, more wolf-like packs, while elk populations soared, changing the vegetation close to rivers by eating young trees and shrubs. Pronghorn antelope populations dropped as more coyotes preyed on their offspring; beavers disappeared from the park and songbirds declined in number.

Reintroducing just 31 wolves in the mid-1950s transformed the ecosystem again. Wolves targeted their closest competitor, killing coyotes in confrontations over carcasses and consuming enough prey to hinder their survival. Coyotes avoided areas favoured by wolves and shifted to smaller prey. Coyote packs fragmented and their overall population declined sharply. More pronghorns survived; elk herds diminished; and riverine vegetation came back, encouraging the return of beavers and songbirds.

"Did we force Neanderthals into extinction? Yes, but not through violence or killing"

In a similar way, Neanderthals bore the brunt of our invasive impact. They might have abandoned areas where their rivals were numerous, as coyotes did, but unlike them did not shift to different prey. Wolves dominate coyotes by sheer size and power. We humans dominated through our diverse hunting skills. One advantage is that we had projectile weapons, while Neanderthals had only handheld or muscle-powered weapons. Distance killing exposed us to far fewer risks and expended less energy. More food for less work meant more energy for reproduction. The second advantage is that, at about the time of the demise of the Neanderthals, we "invented" dogs.

We did not set out to create dogs. There were no other domesticated animals at the time and, until recently, no one thought domestic dogs appeared until about 15,000 years ago. In 2009, a team led by my Belgian colleague Mietje Germonpré began investigating ways to tell dogs apart from wolves using statistical methods. These two canids are so similar that they can and do interbreed; no simple genetic or physical trait distinguishes them. However, a complex analysis of skull shape reliably separates wolves from both modern dogs and from the accepted prehistoric wild dogs. Analysing additional fossil canid skulls, the team recognised a group of ancient dog-like animals intermediate in shape between wolves and prehistoric dogs. I call them

PROFILE
Pat Shipman is a palaeoanthropologist and former adjunct professor of biological anthropology at Pennsylvania State University. Her book *The Invaders: How humans and their dogs drove Neanderthals to extinction* is out this month.

VINCENT J. MUSI/NATIONAL GEOGRAPHIC CREATIVE

wolf-dogs, not because I believe they were hybrids, but because deciding which group they belonged to is not easy.

Whatever wolf-dogs were, they were different from contemporary wolves. Chemical analysis of their bones shows their diets differed from those of humans or wolves at the same sites. Wolf-dog mitochondrial DNA differs from that of any other canid and is very primitive compared with that of other modern and fossil dogs and wolves.

The oldest wolf-dog yet identified (there are now more than 40) is an astonishing 36,000 years old, much older than expected for a domesticated animal. How long would domestication take when no one could possibly know how to do it? The oft-cited silver fox farm experiment, conducted in Siberia, produced a domesticated fox in 40 generations. However, the original foxes were not wild – their ancestors had been in captivity for 50 years – and they were caged, so only those chosen by experimenters bred. These conditions were not like those in the first domestication, which probably took thousands of years of trial and error. If it did, then wolf-dog domestication started before Neanderthals went extinct. The telltale evidence of early domestication should lie in behaviour. Dogs travel with us, bond with us, cooperate with us, and change our lives. They are our best friends. Wolves are not.

The prediction that the presence of wolf-dogs would coincide with a behavioural shift in humans is borne out by the archaeological record. All known wolf-dogs occur in sites created by humans, not Neanderthals. The sites themselves are extraordinary and contain the bones of dozens, even hundreds, of woolly mammoths, though mammoths were previously rare in archaeological sites. Some were clearly hunted, their bones butchered, skinned and charred. The sites include hearths, tools and huts built from mammoth bones. Though top predators are always rare in ecosystems, wolf remains at these sites are so abundant that they must have been targeted. Their luxuriant fur would be useful in near-Arctic conditions, and territorial wolf-dogs – like wolves and dogs today – would probably not tolerate the presence of any other canid.

Even if wolf-dogs were poorly domesticated, cooperating with them would have offered huge advantages. We gave them food, shelter and protection. They provided faster pursuit of prey and the ability to track by smell. They could surround and harass large prey until they tired, making our long-distance weapons more successful and saving wolf-dogs from risk. Territorial wolf-dogs defended the carcasses, the camp and us, enabling us to have longer-term settlements close to the kill site. Wolf-dogs enlarged our ecological niche, enabling us to outcompete Neanderthals.

This hypothesis still requires elaboration and testing. Not everyone accepts the evidence that wolf-dogs were domesticated so very early, or that they were instrumental in pushing Neanderthals into extinction. But I think that the combination of humans and dogs was unstoppable. Since then, we and our best friends have invaded other continents and initiated the sixth global extinction. Working with humans, dogs are deadly weapons. ■

CHANCE

We live in a world of chance and opportunity. But how much is truly random – and how much are we in control of our destinies?

This special report looks at how, through basic quantum and evolutionary processes, chance shapes us from the bottom up – and how we attempt to influence and understand it in our everyday lives

RANDOM REALITY

Does chance rule the cosmos – and if so what does it mean for us, asks *Michael Brooks*

"OH, I am fortune's fool," says Romeo. Rest easy, lover boy; we all are. Or are we?

Romeo, having killed Tybalt and realising he must leave Verona or risk death, was expressing a view common in Shakespeare's time: that we are all marionettes, with some higher cause pulling the strings. Chance – let alone our own decision-making – plays little part in the unravelling of cosmic designs.

Even processes that inherently involved chance were pre-determined. Long before dice were used for gaming, they were used for divination. Ancient thinkers thought the gods determined the outcome of a die roll; the apparent randomness resulted from our ignorance of divine intentions.

Oddly, modern science at first did little to change that view. Isaac Newton devised laws of motion and gravitation that connected everything in the cosmos with a mechanism run by a heavenly hand. The motion of the stars and planets followed the same strict laws as a cart pulled by a donkey. In this clockwork universe, every effect had a traceable cause.

If Newton's universe left little room for randomness, it did at least provide tools to second-guess the Almighty's intentions. If you had all the relevant facts pertaining to a die roll at your fingertips – trajectory, speed, roughness of the surface and so on – you could, in theory, calculate which face would end up on top. In practice this is far too complex a task. But it showed that randomness was nothing intrinsic; just a reflection of our lack of information.

Confidence in cosmic predictability led the French mathematician and physicist Pierre-Simon de Laplace to assert, a century after Newton, that a sufficiently informed intelligence could forecast everything that is going to happen in the universe – and, working backwards, tell you everything that did happen, right back to the cosmic beginnings.

It's a glorious and rather discomfiting idea. If everything really is predictable, then surely all is pre-determined and free will is an illusion? Romeo, in other words, is right. Perhaps so, says physicist Valerio Scarani, who studies randomness and its limits at the Centre for Quantum Technologies in Singapore. "One may believe that a single causal chain determines everything – call it God, the big bang or robots-behind-the-matrix," he says. "Then there is no randomness."

The connection between a universe that admits randomness and one that admits free will is an old one, says Scarani. The 13th century Christian ›

EUGENIA LOLI

STEVE MARCUS/REUTERS

philosopher Thomas Aquinas insisted a perfect universe must contain randomness to allow humans their autonomy. But it was also there to limit them. God made humans with less than divine abilities, so there must be a sphere of events beyond our control.

It wasn't until about two centuries after Newton that anyone began seriously to challenge the notion of a predictable cosmos. In 1859, Scottish physicist James Clerk Maxwell drew attention to the huge disparities in outcome that can stem from tiny factors affecting the collisions of molecules.

This was the beginnings of chaos theory. In its most familiar guise of the butterfly effect – that the flap of a butterfly's wings in Brazil might set off a tornado in Texas, as the chaos theorist Edward Lorenz put it in 1972 – this seems to restore unpredictability to the world. With a sufficiently complex system, even the tiniest approximation while working at the limits of your clock, barometer or ruler, or the slightest rounding error in a computation, can drastically affect the result. This is what makes the weather so hard to predict (see "Risky business: The weather man", page 33). Its eventual state is highly dependent on the initial measurement – and we can never have a perfect initial measurement.

So, small, human-scale decisions might indeed matter on the wider stage. Romeo's predicament traces back to the initial conditions that first put him in the same room as Juliet – or further back still. Take that too far, though, and we might trace them back to before our ancestors came down from the trees, which seems to circumvent any sensible notion of human free will.

It's a head-scratcher, alright – but as yet we are only scratching the surface.

Because while we seem to occupy a reality where causes lead to predictable effects, dig down and that's apparently not how things work at all. Quantum theory, developed in stages since the early 20th century, is our working theory of reality at its most basic – and it does away with cast-iron certainty entirely. "It appears to us, via quantum experiments, that nature is fundamentally random," says Adrian Kent, a mathematician at the University of Cambridge.

PROBABILITY OF 26 CONSECUTIVE BLACK NUMBERS IN ROULETTE: 1 IN 136,823,184

This happened in Monte Carlo in 1913

Fire a single photon of light at a half-silvered mirror, and it might pass through or be reflected: quantum rules give us no way to tell beforehand. Give an electron a choice of two slits in a wall to pass through, and it chooses at random. Wait for a single radioactive atom to emit a particle, and you might wait a millisecond or a century. This rather lackadaisical attitude to classical certainties could even account for why we are here in the first place. A quantum vacuum containing nothing can randomly and spontaneously generate something. Such a careless energy fluctuation might best explain how our universe began.

Explaining the explanation is trickier. We don't know where the quantum rules came from; all we know is that the mathematics behind them, rooted in uncertainty, corresponds to reality observed up close. That starts with the Schrödinger equation, which describes how a quantum particle's properties evolve over time. An electron's position, for example, is given by an "amplitude" smeared over space, and there is a set of mathematical rules you can apply to find the probability that any particular measurement will pinpoint the electron to any particular position.

That's no guarantee the electron will be in that position at any one time. But by repeatedly doing the same measurement, resetting the system each time, the distribution of results will match the Schrödinger equation's predictions. The repeated, predictable patterns of the classical world are ultimately the result of many unpredictable processes.

The repercussions are interesting. Say you want to walk through a wall; quantum theory says it's possible. Each one of your atoms has a position that could – randomly – turn out to be on the other side of the wall when it interacts. That event's probability is exceedingly low, and the probability that all of your

GLOBALLY AVERAGED PROBABILITY OF BEING KILLED BY LIGHTNING: 1 IN 300,000

atoms will simultaneously locate to the other side of the wall is infinitesimally small. A nasty bruise is the sum of all the other probabilities. Welcome to reality.

Einstein was particularly exercised by this probabilistic approach to real-world events, famously complaining it was akin to God playing dice. He conjectured that there must be some missing information that would tell you the measurement's outcome in advance.

Hidden realities

In 1964, the physicist John Bell laid out a way to test for such "hidden variables". His idea has since been implemented time and again, mainly using entangled pairs of photons. Entangled particles are a staple feature of the quantum world. They have interacted at some point in the past and now appear to have shared properties, such that a measurement on particle A will instantaneously affect what you get from a measurement on particle B, and vice versa.

What's behind this? The details of Bell's tests are complex and subtle, but the principle is akin to a sport in which two groups of experimenters play according to different rules. Team Alpha assumes that the quantum correlations are down to some hidden exchange of information, and make measurements accordingly. Team Beta, on the other hand, assumes the correlations materialise at random on measurement.

And Team Beta wins every time. The weird correlations of the quantum world derive from fundamental randomness.

Or do they? Physicists are still investigating loopholes in the way we do quantum measurements that might skew the results and simulate randomness – the fact that we can't measure the state of photons with 100 per cent accuracy, for instance, or even the question of whether we have free will in choosing the measurements we make. "I think it's premature to say we've closed all the important Bell loopholes," says Kent.

It is possible that quantum theory's vagaries might one day be explained, perhaps by compromising some other cherished principle, such as Einstein's relativity. Or maybe someone will come up with some more intuitive, non-random theory that reproduces all the predictions of quantum theory and makes some stronger ones as well. "That hypothetical theory would be a new theory – a successor to quantum theory, not a version of it," Kent says.

Terry Rudolph, a physicist at Imperial College London, agrees. Quantum theory is our ultimate theory of nature, and it seems to suggest the universe is random, but that is no guarantee it is. "I don't think we can ever prove it," he says.

If so, randomness might still prove to be an illusion – and with it, perhaps our free will. "Then quantum physics is just part of the big conspiracy," says Scarani.

Fortune's fools? Perhaps we're not at liberty to decide. ■

Michael Brooks is a consultant for *New Scientist*

MICHAEL ZUMSTEIN/AGENCE VU/CAMERA PRESS

RISKY BUSINESS

THE BOOKIE

ALAN GLYNN

Head of Sports Trading at bookmakers Paddy Power

How do you calculate odds?

You analyse the teams or competitors with the stats you have available. For a Premier League football game, for example, you look at which team is better in the long run, which one has played better recently, where the game is being played, which players are available and any other factors such as how important this particular game is to each team. Having weighed up all these things, you come up with a probability that each team might win.

How much is down to maths and how much to human judgement?

We use algorithms and mathematical models, but very few bookmakers would generate prices and be confident of them using a computer program alone. You need human intervention to make sure everything has been taken into account. For the most part, the final figure comes from the trader's head. This is what bookmaker traders do every day. They're good at it.

There are basic rules to follow. For example, in the Premier League, about 44 per cent of games are won by the home team, 26 per cent by the away team and 30 per cent are a draw. If you had two teams that looked as good as each other, then those are the percentages you would put on the match. That is your starting point. If you thought the home team was slightly better, you might give them 46 per cent chance of a win instead of 44 per cent.

How are the odds affected by the way punters bet?

Usually not at all. In something like a Premier League game, where the public have as much information as we do, we'd be very confident in the odds we set and wouldn't change our prices readily. That's not to say we would never pay attention to where the money goes. You can't know every last detail about every event. If you have the 500th tennis player in the world playing the 550th, clearly information is at a premium. If we saw a run of bets on a game like that we would definitely change our odds, because it could be a key indicator of what's going to happen.

LIFE CHANCES

Evolution is a tug of war between randomness and determinism. But which one wins, asks *Bob Holmes*

TAKE 100 newly formed planets of one Earth mass. Place each in the habitable zone of a G-type main sequence star. Set your timer for 4 billion years. What do you get? A hundred planets teeming with life forms quite similar to those on Earth, perhaps even dominated by naked apes? Or would evolution produce very different outcomes every time, if life even got started at all?

Some biologists argue that evolution is a deterministic process, that similar environments will tend to produce similar outcomes. Others, the most famous of whom was Stephen Jay Gould, think its course follows unpredictable twists and turns, and that the same starting point can lead to very different results.

The answer does matter. If the Gould camp is right, the study of evolution is like the study of history: something we can understand only in retrospect. If, however, the vagaries of chance play just a minor role, then biologists can predict the course of evolution to a large extent – and predicting evolution is crucial to stopping tumours becoming drug-resistant, or bacteria shrugging off an antibiotic, or bedbugs becoming immune to pesticides, or viruses killing people who have been vaccinated against them and so on.

So which is it? We might not have 100 Earths and a time machine, but we can look at how evolution has turned out on, say, neighbouring islands, or even rerun it over and over in the lab. These kinds of studies are giving us a better idea of the role of chance.

First things first. Evolution does begin with chance events, in the form of mutations. But it is not a case of anything goes; far from it. Which mutations survive and spread depends on natural selection – the survival of the fittest. Put another way, chance is the creative partner that comes up with all the ideas – some brilliant, others hopeless – while natural selection is the ruthlessly practical one, picking what works.

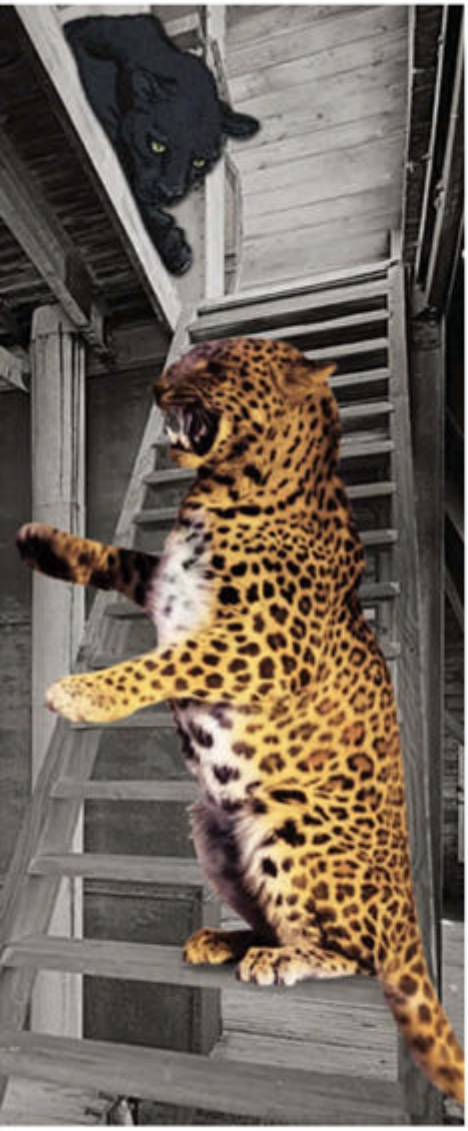
Many biologists, most notably Richard Dawkins, therefore insist that although mutations may be random, evolution is not. This insistence might make sense when explaining evolution to people who have not grasped the basic concept. But there is an element of chance in evolution, even when natural selection is firmly in the driving seat.

Take the evolution of flu viruses.

PROBABILITY OF A RANDOMLY PICKED CLOVER HAVING FOUR LEAVES: ABOUT 1 IN 10,000

We can predict with confidence that, over the next few years, the structure of a viral surface protein called haemagglutinin will evolve so that the human immune system can no longer recognise and attack it. What's more, we can even be fairly sure that the mutations that allow new strains of flu to evade the immune system will happen at one of seven critical sites in the gene coding for haemagglutinin, says Trevor Bedford, an evolutionary biologist at Fred Hutchinson Cancer Research Center in Seattle. In this sense, the evolution of flu is non-random and predictable.

But it's a matter of chance which of those seven sites mutate, and how. Predicting the course of flu's evolution is almost impossible more than a year or two in advance, says Bedford. This is why flu vaccine makers do not always get it right, and why this season's flu vaccine was largely ineffective.



COLLAGE: EUGENIA LOLI; ILLUSTRATION: KATELYN DAUBEK

What's more, as important as natural selection is, its powers are limited. The fittest do not always survive; instead, the course of evolution is often shaped by accidental events. If it hadn't been for an asteroid strike, for instance, we mammals might still be scurrying about in mortal fear of dinosaurs. And if a different bird had been blown to the far-off Galapagos Islands a few million years ago, we might talk about Darwin's crows instead of Darwin's finches.

We've long known about this "founder effect", but recent studies suggest it may be more important than thought. For example, a handful of little birds were the ancestors of several populations of Berthelot's pipit on the Selvagem and Madeira island chains, in the Atlantic. There are big variations among them in the shape and size of beaks, legs and wings.

When Lewis Spurgin of the University of East Anglia in Norwich, UK, studied these populations, he expected to find environmental differences that explained this variation, but he did not. Instead, he concluded that the physical differences were not driven by natural selection but were just a result of the small number of founders: accidents of history, in other words (*Molecular Ecology*, vol 23, p 1028).

Accidental process

The founder effect can even create new species without the need for natural selection. When Daniel Matute, now at the University of North Carolina in Chapel Hill, took a large population of fruit flies and created 1000 founder populations of a single male and female in identical vials in his lab, most populations simply went extinct because of inbreeding. But in three of the surviving populations, the founders produced offspring different enough that they were less able to interbreed with the larger parental population – the first step to the creation of a new species.

Effects like these might explain why the islands of Hawaii have such a rich diversity of fruit flies. In fact, a few biologists think speciation is almost always an accidental process, rather than one driven by natural selection (*New Scientist*, 13 March 2010, p 30).

Yet more evidence of the limits of natural selection comes from genomes, which are littered with the products of chance. Despite many claims to the contrary, most of the human genome is just junk, for instance. This junk has accumulated because natural selection has not been strong enough to remove it, says Michael Lynch, an evolutionary biologist at Indiana University in Bloomington. In small populations, even mutations that are slightly harmful can spread throughout the population simply by chance.

Does this kind of genetic drift really matter? At least sometimes, it does. Joe Thornton of the University of Chicago has been turning back the clock and replaying evolution to see if it could have turned out differently. Think *Jurassic Park*, except rather than recreate extinct animals, Thornton has recreated ancient proteins. His team began with living vertebrates that each have their own version of the ›

RISKY BUSINESS

THE WEATHER MAN

KEN MYLNE

Head of weather science numerical modelling at the UK Met Office

How do you forecast the weather?
We set up a model to represent the current state of the atmosphere based on many observations. From that, the model projects forward in time and calculates how the atmosphere may evolve. The outcome of the forecast is very sensitive to small errors in the initial state, so we run what we call an ensemble forecast. Instead of just running the model once, we make a series of small changes to the initial state and re-run the model a large number of times to get a set of forecasts. On some days the model runs may be similar, which gives us a high level of confidence in the forecast; on other days, the model runs can differ radically so we have to be more cautious.

How certain can you be about forecasts?
The level of confidence varies from day to day and from forecast to forecast. In some circumstances you can get big differences between the forecasts in the ensemble. The biggest uncertainties are often around big storms and the dramatic weather everyone cares about, because the atmosphere has to be in a sensitive, unstable state to generate that high-impact weather. The chaotic nature of the atmospheric system does impose fundamental limits on predictability. In terms of day-to-day weather, that limit is typically between 10 days and two weeks using probabilistic forecasts.

From 2011, the Met Office started presenting rain forecasts using probabilities. Was that controversial?
We'd been debating it for a long time. The Americans have been putting out probability of precipitation forecasts for many years, and it's quite accepted there. The argument in favour is that often you cannot – for good scientific reasons – say definitely that it will or will not be raining. So you are giving people much better information if you tell them the probability of rainfall. While we recognise that some people find probabilities difficult to understand, lots of people do understand them and make better decisions as a result.

PROBABILITY OF A ROYAL FLUSH IN POKER: 1 IN 649,739

gene encoding the protein that detects the stress hormone cortisol. By comparing the versions, they could work out how it had evolved over hundreds of millions of years, from a protein that could detect another hormone.

Then Thornton's team went a lot further. They actually made some of these ancient proteins and tried them out to see what effect each mutation had. Switching to cortisol took five mutations: two to recognise cortisol and three to "forget" the previous hormone.

But when the team made only these five changes, they destabilised the protein and wrecked it. It turns out the transition to cortisol was possible only because two other mutations that stabilise the protein had occurred first. But these "permissive" mutations have no effect by themselves. They must have arisen by chance, not by natural selection (*Science*, vol 317, p 1544).

"We think of these permissive mutations as opening doors, so that evolution has the opportunity to follow pathways that were inaccessible without the permissive mutations," says Thornton. And there seems to be only one way the door to the cortisol-binding pathway could have opened. Thornton tested thousands of other mutations, but none did the trick. "There is nothing else in the neighbourhood around the ancestral protein that could have opened that door," he says.

In Thornton's view, the course of evolution often – although not always – hinges on such seemingly insignificant chance events. In this way, evolution is a lot like life, he notes: a seemingly inconsequential decision one night to go

IOSPHOTO/ALAIN COMPOST

STEVE WINTER/NATIONAL GEOGRAPHIC CREATIVE

to one party rather than another might lead to meeting your future partner and thus change the course of your life.

Then again, who we hook up with seldom alters the course of history. Although all these studies suggest that chance plays a bigger role in evolution than generally acknowledged, the big question is how much difference it makes in the long run. The detailed paths taken by evolving populations might depend largely on chance, yet still lead to similar outcomes. There are only so many ways of flying and swimming, for instance, which is why wings and fins have independently evolved on many occasions. If Thornton's protein hadn't evolved the ability to bind cortisol, perhaps another protein would have instead.

There are many examples of this kind of convergent evolution. Arctic and Antarctic fish have independently evolved antifreeze proteins that work in the same way, for example, while several snake lineages have separately come up with identical methods of coping with the poisons secreted by the newts they eat.

In the Greater Antilles in the Caribbean, meanwhile, evolution has effectively been rerun on four islands – and turned out the same way. Each of the islands has long-legged Anolis lizards that run on the ground, short-legged ones that grasp twigs, and lizards with big toepads that stick to leaves. But each island's lizards seem to derive from a single founder population, meaning they independently evolved to fill the same niches.

Does this mean Gould was wrong after all, that in the long run chance does not matter that much? Perhaps the closest we can get to an answer is the Long-Term Experimental Evolution Project, led by Richard Lenski of Michigan State University. On 24 February 1988, Lenski took samples of one kind of *E. coli* bacteria and used them to found 12 new populations. Every day since then – on weekends and holidays, despite blizzards and grant deadlines – someone has kept them growing by transferring samples to new nutrient medium.

Replaying evolution

In the 27 years that have passed, Lenski's populations evolved for about 60,000 generations. For comparison, *Homo sapiens* has gone through perhaps 20,000 generations in its entire existence. All 12 populations have changed in similar ways, evolving larger cells and faster growth rates, showing that sometimes evolution really does unfold in predictable ways.

But even without external events like asteroid strikes, its course was not always predictable. One population evolved into a mix of two lineages, each of which

survive because they pursue slightly different strategies. Another suddenly developed, at about the 31,500th generation, the ability to feed on citrate, an additive to the culture medium that *E. coli* cannot normally use. "They started from the same place and were subjected to exactly the same conditions, and differences still pop up," says Zachary Blount, who works with Lenski on the project. "The differences arise purely out of the chance that is inherent in the evolutionary process."

Was the citrate-using mutation a lucky break, or could evolution find it again? Because Lenski's team freezes a sample of each culture every 500 generations, Blount was able to go back into the archives of this population and literally rerun evolution. When he did so, the only time citrate use evolved was when he began the replay with cells from the 20,000th generation or later.

Clearly, some mutation or mutations must have happened around the 20,000th generation that set the stage for citrate use to evolve much later, just as Thornton's hormone receptor required permissive mutations before it could switch to recognise a different target. "We still haven't figured out what that mutation was, which is really frustrating," says Blount. Until they can, the team will not know whether the permissive mutation offered some other advantage to the bacteria. Even if it did, however, it seems clear that its role in permitting citrate use must have been just a lucky by-product.

So what would we get if we could replay evolution over and over on a planetary scale? One possibility is an awful lot of slime. Nick Lane of University College London thinks that the emergence of complex cells depended on a highly unlikely merger of two kinds of simple cell (*New Scientist*, 23 June 2012, p 32). If he's right, bacteria-like life forms are common on other worlds but rarely give rise to more sophisticated organisms.

No naked apes

But assuming life did get past the slime stage on our worlds, what would it be like? "There is a fairly good chance that such replays would often yield worlds that look broadly like ours in terms of what niches are filled, and what sorts of major traits you see," says Blount. In other words, you'd still expect to see photosynthesisers and predators, and parasites and decomposers. But the details are likely to differ sharply from one replay to the next, he says. Even if we replayed evolution a hundred times, it's highly unlikely that we would end up again with a big-brained primate ruling the planet.

But would some other brainy, social animal take over the planet? Maybe. "There's clearly an adaptive zone in most habitats that involves intelligence," says David Jablonski, a palaeontologist at the University of Chicago. And it has become clear that many traits we once thought of as uniquely human, from language to tool-making, exist to some extent in many other animals. So although naked apes might not emerge on any of the 100 planets, other smart tool-users might.

It is a question we might even be able to answer one day. Thousands of exoplanets have now been discovered and even though we've yet to find any just like ours, all the evidence suggests there are plenty of Earth-like planets close enough that we might not only determine whether they support life, but also learn a little about it. The answer may be in the stars. ■

Bob Holmes is a correspondent for *New Scientist* based in Edmonton, Canada

RISKY BUSINESS

THE GAMBLER

VANESSA SELBST

Highest earning female poker player of all time

So, that old question: how much is poker about luck?
Luck is a huge factor. Your job as a poker player is to identify the situations in which you have a very good chance of winning and risk as much money as possible. The skilful players will give themselves a better chance of winning, but no matter how good you are, there is so much luck involved in any specific hand. Of course, given the law of large numbers, the luck eventually runs out. So the more tournaments you play, the less luck is involved in the game.

How important is it to understand probability theory?
There is a lot of simple maths you need to know and memorise. For instance, what are the odds of making a flush [five cards of the same suit] if you have two in your hand and there are two on the table? After that, the maths is just one of many factors you can use to figure out what someone has in her hand. There are "maths players" who rely mostly on that aspect, but normally you use some combination of maths, deductive reasoning and psychology. For me, reasoning is the biggest part of it – taking all the possibilities and illuminating each possibility until I end up with the most likely scenario.

Do you think of yourself as a gambler?
I don't really like to gamble, which is a funny thing for a professional gambler to say. But I prefer not to. If I bet this hand and I know I have a 60 per cent chance of winning, I would much rather you paid me 60 per cent of the pot right now than allow the cards to determine the fate of the hand. But unfortunately for me, that's not part of the game.

How do you cope with losing?
You will inevitably have down swings – I'm in one right now. There have been lots of situations where I've had an 80 per cent chance of winning and lost. It's happened an incomprehensible number of times in a row, something like 20 of the last 25 tournaments. Those situations can be demoralising, but poker players have to be rational.

THINK OF A NUMBER

Chances are it won't be random, says *Michael Brooks*

MADS Haahr is in no doubt. "Generating randomness is not a task that should be left to humans," he says.

You might expect him to say that. A computer scientist at Trinity College Dublin, he is the creator of a popular online random number generator, hosted at random.org. But he has a point.

Human brains are wired to spot and generate patterns. That is useful when it's all about seeing predators on the savannah before they see you, but it handicaps us when we need to think in random and unpredictable ways. That's a problem, because true randomness is a useful thing to have. Random numbers are used in cryptography, computing, design and many other applications. Our inability to "do" random means that we usually have to outsource it to machines.

But relying on outside sources of randomness has its own problems. The first dice for divination and gaming were six-sided bones from the heels of sheep, with numbers carved into the faces. The shape made some numbers more likely to appear than others, giving a decisive advantage to those who understood its properties.

Suspicion about the reliability of randomness generators remains with modern equivalents like casino dice, roulette wheels or lottery balls. But it is online where it really matters. Generating random strings of numbers is essential not just for gambling games or shuffling songs on your iPod, but also to produce unguessable keys used to encrypt sensitive digital information. "I don't think people are very conscious of how important randomness is for the security of their data," says Haahr.

And it takes more than programming. You can't just give computers rules to create random numbers; that wouldn't be random. Instead you might use an algorithm to "seed" a random-looking output from a smaller, unpredictable input: use the date and time to determine which random digits to extract from a random number string such as pi, say, and work from there. The problem is that such "pseudorandom" numbers are limited by the input, and tend to repeat non-randomly after a certain time in a way that is guessable if you see enough of them.

An alternative is to hook up your computer to some source of physical, "true" randomness. In the 1950s, the UK Post Office wanted a way to generate industrial quantities of random numbers to pick the winners of its Premium Bonds lottery. The job fell to the designers of the pioneering Colossus computer,

PROBABILITY OF PAUL THE OCTOPUS CORRECTLY PREDICTING THE RESULTS OF 8 WORLD CUP GAMES: 1 IN 256

developed to crack Nazi Germany's Enigma codes. They created ERNIE, the Electronic Random Number Indicator Equipment, which harnessed the chaotic trajectories of electrons passing through neon tubes to produce a randomly timed series of electronic pulses that seeded a random number.

ERNIE is now in his fourth iteration and is a simpler soul, relying on thermal noise from transistors to generate randomness. Many modern computing applications use a similar source, collected using on-chip generating units such as Intel's RdRand and Via's Padlock. Haahr's generator takes its seed from intrinsically noisy atmospheric processes.

Two problems remain. First, with enough computing power anyone can, in theory, reconstruct the processes of classical physics that created the random numbers. Second, and more practically, random number generators based solely on physical processes often can't produce random bits fast enough.

Many systems, such as the Unix-based platforms used by Apple, get round the first problem by combining the output from on-chip randomness generators with the contents of an "entropy pool", filled with other random contributions. This could be anything from thermal noise in devices connected to the computer to the random timings of the

EUGENIA LOLI

user's keyboard strokes. The components are then combined using a "hash function" to generate a single random number. Hash functions are the mathematical equivalent of stirring ink into water: there's no known way to work out what the set of inputs was, given the number the function spits out.

That doesn't mean there couldn't be in the future – and there's still the speed problem. The workaround is generally to use a physical random number generator only as a seed for a program that generates a more abundant flow.

There we are back with the algorithm problem. The precise nature of the methods these programs use is proprietary, but in 2013 security analysts raised concerns that the US National Security Agency knew the internal workings of one such generator, called Dual_EC_DRBG, potentially allowing them to break encryptions that relied on it. If you're just playing online games, that's not a big problem. But when making multibillion-dollar financial transactions, or encrypting sensitive documents, a suspicion that you are being watched is a bigger deal.

Gaming the system

Such difficulties lead some researchers to suggest we'll never have an uncrackable source of randomness as long as we rely on the classical world, where randomness is not intrinsic, but down to who has what information (see "Random reality", page 28). For safer encryption, we must turn to quantum physics, where things truly do seem random. Instead of a coin toss, you might ask whether a photon hitting a half-silvered mirror passed through it or was reflected. Instead of rolling a die, you might present an electron with a choice of six circuits to pass through. "As a mathematician, I like my randomness to come with proof, and quantum random numbers give us that," says Carl Miller of the University of Michigan in Ann Arbor. "It's unique in that respect."

Cryptographic systems that exploit the vagaries of quantum theory for more secure communication do exist. But they are not the last word in security. Extracting quantum randomness always involves someone making non-random choices about equipment, measurements and such like. The less-than-perfect efficiency of photon detectors used in some methods could also provide a back door through which non-randomness can slip in.

One way out that is still under investigation might be to amplify quantum randomness so you always have more of it than anyone can hack. Ways exist in theory to turn n random bits into 2^n bits of pure randomness, and also to launder bits to remove any correlation with the device that first made them.

Such device-independent quantum random number generation is just the latest development in our search for true randomness. Chances are, this too will soon become reality – only then for someone to find a way to game it. With humans forever in the mix, it could be that we'll always be searching for randomness we can rely on. ■

Michael Brooks is a consultant for *New Scientist*

RISKY BUSINESS

THE AVALANCHE PREDICTOR

MARK DIGGINS

Coordinator of the Scottish Avalanche Information Service in Aviemore

How do you go about assessing a slope for avalanche risk?
You take a sample of the snow by digging down to ground level so you can see all the layers. We are really interested in the interfaces between the layers, because that is where the snow is going to fail. This will provide 15 to 20 per cent of our information. The rest comes from travelling to different parts of the mountain so we can see how the hazard is distributed across the landscape. We can then present a map of avalanche risk for a region. But there's always uncertainty because of the weather, the way the snow lies and the way it's distributed by the wind.

We know a lot about the dynamics of avalanches, yet people are still regularly killed by them. Why is that?
When I first started forecasting avalanches, we were looking for an answer in the snow. We would tap it, pull it, test its stability, then we'd predict whether it would avalanche or not. Today we know that we can't rely on a sample applying to the whole slope, because there is great spatial variability. You could have a weakness in one place, and 2 metres away it could be the opposite. It's a bit of a lottery. A number of people can go down a slope and it can be OK, and then another person goes down and they trigger an avalanche because the wind has moved some snow or there are local differences in the layers.

Do people with more experience or training take fewer risks?
None of us is immune. Studies of avalanche victims have shown that even experienced people are strongly influenced by heuristics – behavioural biases – when they make decisions about the hazard. They may ski a slope because they've done it before, or because other people are skiing it, or because they made a prior commitment to do it. Whether or not they have avalanche training makes no difference.

EUGENIA LOLI

PROBABILITY WARS

Can't get your head around uncertainty? You're in good company, says *Regina Nuzzo*

WE ARE in a bar, and agree to toss a coin for the next round. Heads, I pay; tails, the drinks are on you. What are your chances of a free pint?

Most people – sober ones, at least – would agree: evens.

Then I flip the coin and catch it, but hide in it the palm of my hand. What's your probability of free beer now?

Broadly speaking, there are two answers: (1) it is still 50 per cent, until you have reason to think otherwise; (2) assigning a probability to an event that has already happened is nonsense.

Which answer you incline towards reveals where you stand in a 250-year-old, sometimes strangely vicious debate on the nature of probability and statistics. It is the spat between frequentist and Bayesian statistics, and it is more than an esoteric problem. "The frequentist-Bayesian debate is the only scientific controversy that actually does affect everybody's life," says Larry Wasserman of Carnegie Mellon University in Pittsburgh, Pennsylvania. A drugs company testing a new drug can come to apparently very different conclusions according to which method it uses to analyse its results. A jury might reach a different decision after hearing evidence presented in frequentist and Bayesian terms. "It's not just philosophy, and it's not just mathematics. It really is concrete," says Wasserman.

The two approaches have often seemed at loggerheads. But statisticians are slowly coming to a new appreciation: in a world of messy, incomplete information, the best way might be to combine the two very different worlds of probability – or at least mix them up a little.

To fully appreciate the profundity of our bar bet, let's start with an old T-shirt slogan: "Statistics means never having to say you're certain." Drawing conclusions without all the facts is the bread-and-butter of statistics. How many people in a country support legalising cannabis? You can't ask all of them. Is a run of hotter summers consistent with natural variability, or a trend? There's no way to look into the future to say definitively.

LIFETIME CHANCE OF BEING KILLED BY A DOG IN THE US: 1 IN 103,798

Source: US National Safety Council

Answers to such questions generally come with a probability attached. But that single number often masks a crucial distinction between two different sorts of uncertainty: stuff we don't know, and stuff we can't know.

Can't-know uncertainty results from real-world processes whose outcomes appear random to all who look at them: how a die rolls, where a roulette wheel stops, when exactly an atom in a radioactive sample will decay. This is the world of frequentist probability, because if you roll enough dice or observe enough atoms decaying, you can get a reasonable handle on the relative frequency of different outcomes, and can construct a measure of their probabilities.

Ignorance is Bayesian

Don't-know uncertainty is more slippery. Here individual ignorance, not universal randomness, is at play. What's the sex of William and Kate's new baby? We don't yet know – although it is already a given. Who will win the cricket world cup? That is not a given – the tournament is still ongoing but the preliminary rounds will at least have given you a sense of who is in with a chance (assuming you care).

How to approach these different types of uncertainty divides frequentists and Bayesians. A strict frequentist has no truck with don't-know uncertainty, or any probability measure that can't be derived from repeatable experiments, random number generators, surveys of a random population sample and the like. A Bayesian, meanwhile, doesn't bat an eyelid at using other "priors" – knowledge gleaned from past voting patterns in the cricket example, for example – to fill in the gaps. "Bayesians are happy to put probabilities on statements about the world," says Tony O'Hagan, a statistician at the University of Sheffield, UK, who researches Bayesian methods. "Frequentists aren't."

The coin-in-the-pub example shows where these two views diverge. Before I flip the coin, frequentist and Bayesian probabilities line up: 50 per cent. Then the source of uncertainty changes from intrinsic randomness to personal ignorance. Only if you were inclined to Bayesian ways of working would you be happy to quote a probability figure. That figure might be 50 per cent – or perhaps a telltale flicker of a victorious smile on my face might persuade you to downgrade your chances of a free drink to just 20 per cent, say. "In the Bayesian approach we try to answer questions by bringing all the relevant evidence to bear on it, even when the contribution of some of that evidence to the question depends on subjective judgements," says O'Hagan.

Bayesianism takes its name from the English mathematician and Presbyterian minister Thomas Bayes. In an essay published in 1763, two years after his death, he set out a new approach to a fundamental puzzle: how to work backwards from observations to hidden causes when your information is incomplete. Imagine you have a box of a dozen doughnuts, half cream, half jelly-filled. It's relatively straightforward to calculate the probability of pulling out five jelly doughnuts in a row. But the backwards problem, working out the probable contents of an unknown box when you've just pulled out five jellies, is trickier. Bayes's innovation was to provide the seed of a mathematical framework that allowed you to start with a guess (perhaps you've bought boxes of doughnuts from that store before), and refine it as further data came to light.

In the late 18th and early 19th centuries, Bayesian-style methods helped tame a range of inscrutable problems, from estimating the mass of Jupiter to calculating the number of boys born worldwide for every girl. But it gradually fell out of favour, victim of a dawning era of big data. Everything from improved astronomical observations to newly published statistical tables of mortality, disease and crime conveyed a reassuring air of objectivity. Bayes's methods of educated guesswork seem hopelessly old-fashioned, and rather unscientific by contrast. Frequentism, with its emphasis on dispassionate number crunching of the results of randomised experiments, came increasingly into vogue.

The advent of quantum theory in the early 20th century, which re-expressed even reality in the language of frequentist probability (see "Random reality", page 28), provided a further spur to that development. The two strands of thought in statistics gradually drifted further apart. Adherents ended up submitting ›

RISKY BUSINESS

THE MONEY MAN

EMANUEL DERMAN

Former quantitative analyst at Goldman Sachs

You used to be a physicist. Are there laws of financial markets in the same way there are laws of physics?
In my opinion, absolutely not. In physics you have absolute values. If you want to shoot a rocket to the moon, you can use Newton's laws and the gravitational constant. In finance you can't make absolute predictions. You try to figure out the value of something by relating it to the value of something more simple. If you tell me the price of a one-bedroom apartment, for example, I can give you a guesstimate for a 14-bedroom apartment. Most financial modelling is a more sophisticated version of that.

Is there any predictive model of markets that investors can rely on?
There is, but only for short periods of time. The world keeps changing. People change their behaviour and then markets behave differently. I don't think there is one absolute law or statistical distribution that describes stock prices or interest rates. The probability of a stock market crash in New York, for example, depends on all kinds of detailed political and geographical information. It's not like flipping coins: if a coin came up heads yesterday it doesn't affect the way it will come up today.

How do you explain that behaviour?
Markets are affected by people and people are prone to all sorts of behaviour. They make decisions in complicated ways: they are influenced by what's going on around them and by their prejudices and thinking. It's a kind of idolatry to think you can write down one equation that will describe accurately the way collections of people behave. I'm not saying prediction is a waste of time. I'm just saying that you have to look over your shoulder all the time and understand that it works for a small range of market behaviour in the area you're currently in. At some point things are going to change and then all bets are off about your model.

work to their own journals, attending their own conferences and even forming their own university departments. Emotions often ran high. The author Sharon Bertsch McGrayne recalls that when she started researching her book on the history of Bayesian ideas, *The Theory That Would Not Die*, one frequentist-leaning statistician berated her down the phone for attempting to legitimise Bayesianism. In return, Bayesians developed a sort of persecution complex, says Robert Kass at Carnegie Mellon. "Some Bayesians got very self-righteous, with a kind of religious zealotry."

BRUCE FORSTER/GETTY

Flexible friend

In truth, though, both methods have their strengths and weaknesses. Where data points are scant and there is little chance of repeating an experiment, Bayesian methods can excel in squeezing out information. Take astrophysics as an example. A supernova explosion in a nearby galaxy, the Large Magellanic Cloud, seen in 1987, provided a chance to test long-held theories about the flux of neutrinos from such an event – but detectors picked up only 24 of these slippery particles. Without data, frequentist methods fell down – but the flexible, information-borrowing Bayesian approach provided an ideal way to assess the merits of different competing theories.

It helped that well-grounded theories provided good priors to start that analysis. Where these don't exist, a Bayesian analysis can easily be a case of garbage in, garbage out. It's one reason why courts of law have been wary to adopt Bayesian methods, even though on the face of it they are an ideal way to synthesise messy evidence from many sources. In a 1993 New Jersey paternity case that used Bayesian statistics, the court decided jurors should use their own individual priors for the likelihood of the defendant having fathered the child, even though this would give each juror a different final statistical estimate of guilt. "There's no such thing as a right or wrong Bayesian answer," says Wasserman. "It's very postmodern."

Finding good priors can also demand an impossible depth of knowledge. Researchers searching for a cause for Alzheimer's disease, for instance, might test 5000 genes. Bayesian methods would mean providing 5000 priors for the likely contribution of each gene, plus another 25 million if they wanted to look for pairs of genes working together. "No one could construct a reasonable prior for such a high dimensional problem," says Wasserman. "And even if they did, no one else would believe it."

To be fair, without any background information, standard frequentist methods of sifting through many tiny genetic effects would have a hard time letting the truly important genes and combinations of genes rise to the top of the pile. But this is perhaps a problem more easily dealt with than conjuring up 25 million coherent Bayesian guesses.

Frequentism in general works well where plentiful data should speak in the most objective way possible. One high-profile example is the search for the Higgs boson, completed in 2012 at the CERN particle physics laboratory near Geneva, Switzerland. The analysis teams concluded that if in fact there were no Higgs boson, then a pattern of data as surprising as, or more surprising than, what was observed would be expected in only one in 3.5 million hypothetical repeated trials. That is so unlikely that the team felt comfortable rejecting the idea of a universe without a Higgs boson.

That wording may seem convoluted, and highlights frequentism's main weakness: the way it ties itself in knots through its disdain for all don't-know uncertainties. The Higgs boson either exists or it doesn't, and any inability to say one way or the other is purely down to lack of information. A strict frequentist can't actually make a direct statement of the probability of its existing or not – as indeed the CERN researchers were careful not to (although certain sections of the media and others were freer).

PROBABILITY OF TWO CHILDREN IN A CLASS OF 25 SHARING A BIRTHDAY: 56.9%

Head-to-head comparisons can point to the confusions that can arise, as was the case with a controversial clinical trial of two heart-attack drugs, streptokinase and tissue plasminogen activator, in the 1990s. The first, frequentist analysis gave a "p value" of 0.001 to a study seeming to show that more patients survived after the newer, more expensive tissue plasminogen activator therapy. This

GLOBAL PROBABILITY OF BEING BORN A GIRL: 48.3%

Source: CIA factbook

equates to saying that if the two drugs had the same mortality rate, then data at least as extreme as the observed rates would occur only once in every 1000 repeated trials.

That doesn't mean the researchers were 99.9 per cent certain the new drug was superior – although again it is often interpreted that way. When other researchers conducted a Bayesian reanalysis using the results of previous clinical trials as a prior, they found a direct probability of the new drug being superior of only about 17 per cent. "In Bayesianism we're directly addressing the question of interest, talking about how likely it is to be true," says David Spiegelhalter of the University of Cambridge. "Who wouldn't want to talk about that?"

Perhaps it's just a case of horses for courses, but don't the strengths and weaknesses of both approaches suggest we might be better off combining elements of both? Kass is one of a new breed of statisticians doing just that. "To me statistics is like a language," he says. "You can be conversant in both French and English and switch back and forth comfortably."

Stephen Senn, a drugs statistician at the Luxembourg Institute of Health agrees. "I use what I call 'mongrel statistics', a little bit of everything," he says. "I often work in a frequentist mode, but I reserve right to do Bayesian analyses and think in a Bayesian way."

Kass points to an analysis he and his colleagues did on the firing rates of a couple of hundred neurons in the visual-motor region of the brain in monkeys. Prior work in basic neurobiology provided them with information on how fast these neurons should be firing, and how quickly the rate might change over time. They incorporated this into a Bayesian approach, then switched gears to evaluate their results under a standard frequentist framework. The Bayesian prior gave the methods enough of a kick-start to allow frequentist methods to detect even tiny differences in a sea of noisy data. The two approaches together trumped either method alone.

Sometimes, Bayesian and frequentist ideas can be blended so much they create something new. In large genomics studies, a Bayesian analysis might exploit the fact that a study testing the effects of 2000 genes is almost like 2000 parallel experiments, and cross-fertilise the analyses, using the results from some to establish priors for others and using that to hone the conclusions of a frequentist analysis. "This approach gives quite a bit better results," says Jeff Leek of Johns Hopkins University in Baltimore, Maryland. "It's really transformed the way we analyse genomic data."

It breaks down barriers, too. "Is this approach frequentist? Bayesian?" asked Harvard University statistician Rafael Irizarry in a blog post. "To this applied statistician, it doesn't really matter."

Not that the arguments have entirely gone away. "Statistics is essentially the abstract language that science uses on top of data to tell stories about how nature works, and there is not one unique way to tell stories," says Kass. "Two hundred years from now there might be some breakthrough connecting Bayesianism and frequentism into a grand synthesis, but my guess is that there will always be at least one versus the other."

So chances are in 2215, two people will still be sitting on pub stools arguing about their chances of free beer. ■

Regina Nuzzo is a science writer and statistics instructor based in Washington DC

RISKY BUSINESS

THE MATHEMATICIAN

DAVID HAND

Emeritus professor, Imperial College London

In your recent book *The Improbability Principle*, you state that extremely unlikely events are commonplace. How so?

At first glance, it sounds like a contradiction: if something is highly improbable, how can it possibly be commonplace? But as you dig deeper you see it is not a contradiction, and that you should expect what appear to be extremely improbable events to occur quite often. The principle itself is really an interweaving of five fundamental laws.

Could you give an example of one of those laws?

Take the law of truly large numbers. The most obvious example of this is the lottery. In the UK you have a 1 in 14 million chance of winning if you buy just one ticket. But of course if you get enough people buying enough tickets it becomes almost inevitable that somebody somewhere will win. Another example is the chance of being struck by lightning. Around the world there's a 1 in 300,000 chance of being killed by lightning in any one year. The rational thing is to behave as if it's not going to happen to you. But there are 7 billion people in the world, so there are a lot of opportunities for it to happen. In fact the chance that no one will be killed is about $10^{-10,133}$. So we should expect to see someone killed. In fact about 24,000 people every year are killed by lightning, and about 10 times that many are injured.

People often notice coincidences and patterns that aren't really there. Why?

Our ancestors survived in the world because they identified patterns: if you responded to movements in the grass you could avoid being killed by an approaching tiger. So there's an evolutionary reason. But a lot of what look like patterns in data just appear by chance.

Interviews by Michael Bond. Extended version of all the "Risky Business" interviews on these pages can be found at newscientist.com/special/chance

Good lives for all?

If we want to reach true global sustainability, what price optimism, wonders **Fred Pearce**

The Age of Sustainable Development by Jeffrey Sachs , Columbia University Press, $34.95/£23.95

THE great thing about Jeffrey Sachs is his optimism. The US guru of sustainable development strives hard in his latest work, *The Age of Sustainable Development*, to persuade us that we can save the world and all live the good life – all 7,8,9, or eventually even 10 billion of us.

The other big thing about Sachs, who in his day job is director of Columbia University's Earth Institute in New York, is his network of contacts. He is politically hyperconnected, a friend of world leaders, and able to get the UN secretary general Ban Ki-moon to write a foreword for the new book. So if anyone can persuade those leaders that they should do what it takes, then it is Sachs. But what exactly is the sustainability blueprint?

Sustainable development is a deceptively simple idea: we should manage the world's affairs so as not to destroy the place for our children. Who could disagree? But since the idea became a touchstone for international policy-makers about 30 years ago, it has become mired in confusion.

At its root, Sachs insists that sustainable development is an academic discipline. He calls it "a way to understand the world as a complex interaction of economic, social, environmental and political systems" – systems whose analyses conventionally share neither a language nor a way of thinking. But more than that, it attempts to combine an academic approach with an ethical outlook to help create policy prescriptions. "It is also a normative or ethical view of the world… one that delivers wellbeing for its citizens today and for future generations," he argues.

"Sustainable development is a deceptively simple idea, but has become mired in confusion"

This book is a heroic attempt to combine this ambitious agenda in an accessible, jargon-free way that politicians – and the rest of us – might sign up to.

The themes are familiar enough: globalised economic growth has generated "fabulous wealth", but also extreme poverty, a soaring population and potentially catastrophic disruption of key planetary processes such as the carbon, water and nitrogen cycles – disruption that, Sachs says, threatens the physical basis of our very survival.

He pulls no punches in his diagnosis. But what sets Sachs apart is the determined optimism of his prognosis. He believes both in technology's ability to deliver good lives without breaking the planet's life-support systems, and in the ability of governments to organise for the task ahead.

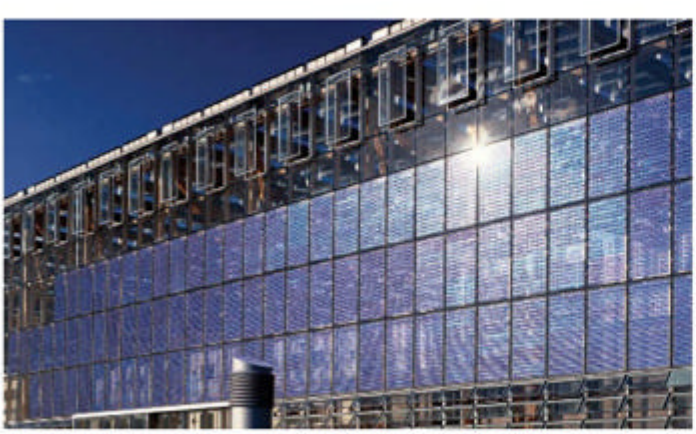
Sachs is no hair-shirt environmentalist. Many others, he notes, argue that to save our world, we need to halt the economic juggernaut that has taken us to the "planetary boundaries", beyond which breakdown would ensue. "I argue differently," he says. Our salvation, he believes, lies not in painful trade-offs between getting rich and saving the planet, but in finding virtuous synergies.

Choosing the right technologies, he says, we can achieve continued economic growth and also honour the planetary boundaries. We can grow more food with less water and fertiliser; we can generate more energy while burning much less carbon; and we can bring greater fairness to the human world without sacrificing economic growth or efficiency.

His techno-optimism leads him to believe in nuclear power, in "smart" cities as crucibles of innovation and, more cautiously, in GM technology. He embraces the theories of Russian economist Nikolai Kondratiev about how the world's economic advances have been driven by successive bursts of technological change: steam engines, railways and steel, electrification and chemicals, automobiles, the digital revolution, and now – Sachs hopes – a sustainability revolution. It will be built around nanotechnology, smart agriculture, renewable energy

ULRICH MERTENS/PLAINPICTURE

Green tech and smart cities may carry their own environmental costs



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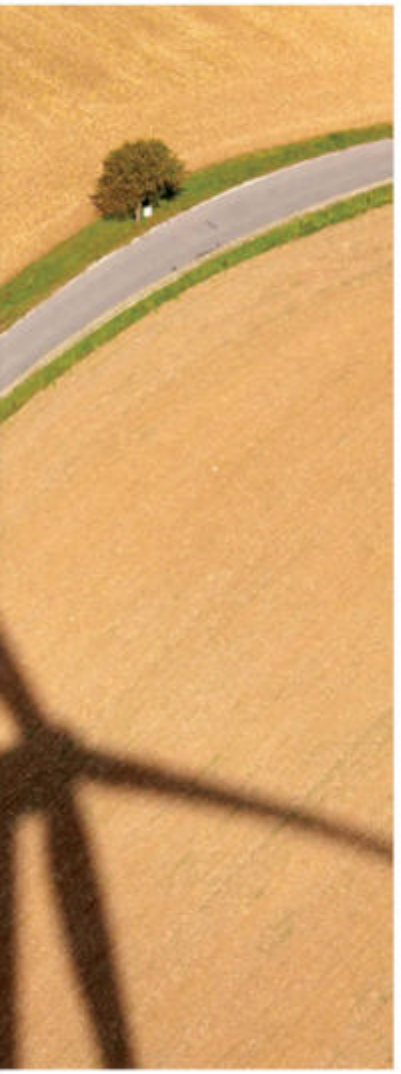

and big efficiency gains, all driven by new skills gained in the digital revolution.

Perhaps the most striking thing about his manifesto for sustainability, however, is its political optimism. He believes in government and in the transformative powers of political leaders to deliver a better world. He is convinced, for instance, that sub-Saharan Africa – the apparent antithesis of sustainability, where extreme poverty, social disintegration, environmental degradation and bad government seem in gruesome harness – is taking a turn for the better.

For him, that is symbolised by the ability of governments there in the past five years to finally get a grip on the region's biggest health hazard, malaria.

But I found him least convincing when he explains exactly how politics will deliver – especially in the areas of international governance where his globetrotting pedigree and UN links would suggest he could offer the greatest insights. His analysis of this is surprisingly sketchy, given how important he thinks politicians are in delivering a sustainable world.

He lapses instead into UN-speak, and is almost silent on the politics of global trade and resource "grabs" by international capital. Surely these are central to the growing global inequalities that he sees as fundamental social and economic barriers to sustainability?

And his chapter on climate change is weighed down by pessimism about the power of fossil-fuel lobbies to stymie action. "The global politics of climate change have been largely stuck since 1992," he writes. If climate change is, as he says, the biggest problem facing the world, then that observation makes his broad-brush political optimism seem shallow and naive.

In this, he is not alone. The sustainable-development community may have a clear idea about where it wants to get to; it may see the technological road ahead; and it may see that there are no insurmountable roadblocks. But it does not yet have a clear political narrative for how to get to the promised land.

As the quote on the cover of my edition suggests, Sachs has probably produced the best book to date on how to manage the planet for 10 billion people. Sadly, the best is not good enough. If we really want to reach an age of sustainability, it will take more than optimism. ■

Fred Pearce is a consultant for *New Scientist*

STEPHEN FRINK/AURORA

Sharks and criminals

New digital monitoring can backfire on conservation efforts, finds **Tim Maughan**

Digital Animals conference, New York University

THERE'S a lot of talk about the internet of things, said Etienne Benson, "and increasingly some of them are living things". Benson, from the University of Pennsylvania in Philadelphia, was speaking last month at Digital Animals, a one-day conference examining how digital perspectives and technologies will change animal protection.

Benson cited Western Australia's Sharksmart tracking system. Using data from sharks tagged by researchers, the network produces interactive maps, alerts and warnings on the animals' activity near Western Australia's beaches. Sharksmart made global headlines when the decision was made to destroy a shark purely on the basis of tagging data that showed it was frequenting a popular swimming and surfing area.

To Benson, this reveals a worrying shift in the philosophy behind tagging animals. Among Western Australia's sharks, Benson argues, the tags have become a technology of control and punishment. Sharks are literally being treated like criminals.

Also tracking animals, although for different reasons, is Thomas Snitch, whose company flies fixed-wing drones across central and southern Africa to protect rhinos and elephants from poachers. A mathematician, Snitch has worked as an analyst for the US military, studying maps of Iraq and Afghanistan to work out where insurgents were likely to have placed explosive devices. The drones are less important than the algorithms that decide where they should be flown, he says. Since October 2014, no rhinos have been killed in areas the drones patrol.

Anna Frostic of the Humane Society of the United States was concerned with social media's obsession with "cute" animals: specifically, how websites and social media feed a demand for exotic pets. There are now more tigers in captivity in the US than in the wild globally. Chimps appear everywhere online, so charities struggle to convince people that the species is endangered.

The take-home message was that while all these technologies raise our awareness of animal-protection issues, they also inflict inadvertent damage and need close monitoring. ■

Real morality in a virtual world

Are the rules the same online? **Sumit Paul-Choudhury** hunts for compasses

The Nether by Jennifer Haley, Duke of York's Theatre, London, until 25 April

"WHO are we when we live without consequences?" That's the question a detective poses angrily to the owner of the Hideaway, a virtual clubhouse catering to paedophiles, in Jennifer Haley's charged, compact play about online morality.

The "Nether", a fully immersive relative of the internet, lets them indulge in fantasies of molestation and murder – without meeting an actual child. To Morris, the detective, the corruption of the clientele is real, even if their victims are not. Yet for all her fury, she cannot induce Poppa, the Hideaway's charismatic proprietor, to admit he has done anything wrong.

Indeed, he insists that in his closely regulated realm – an idyllic and stunningly realised colonial mansion – customers can expend their urges safely. Everyone consents, no one comes to harm, and they are happy, in a way that they could never be in the real world. What's wrong with that?

This is not a comfortable scenario, and *The Nether* is not a comfortable play; it takes courage to present paedophiles in terms other than condemnation. Yet Haley's script does not require us to condone paedophilia, only to recognise that paedophiles have desires, motives and emotions too. And it is remarkable how the characters retain their complex humanity no matter what virtual atrocities they have committed.

It reminds us that if we regard them as "sick", we must also think of them as needing cures. For those wary of what they might see, by the way, the play's power relies on suggestion, not shock.

The audience faces unanswered, and perhaps unanswerable, moral propositions at every turn. Is freedom of speech absolute? Should you be prosecuted for the contents of your imagination? If no one is forced to act against their will, should such actions nonetheless be forbidden?

Stripped of real-world complications, the arguments are pared to their essentials, sometimes leaving characters and audience scrabbling for purchase. For example, Morris is desperate to learn whether there was ever "a real girl" beneath the Hideaway's simulacrum of 11-year-old Iris. The implication is that Poppa would then be complicit in abuse, just as those who trade images of abuse today are complicit in their manufacture.

But every time the audience thinks certitude nears, Haley snatches it away. By assuming the technology and abstracting the problem, she allows the audience to focus on the Socratic method at the play's core and weigh up the protagonists' arguments in a relatively cool-headed manner.

"Virtual children have ensnared paedophiles, yet childlike robots could be used to treat them"

At loggerheads: is a virtual simulation of a crime still a crime?

JOHAN PERSSON

And although Haley has picked the most extreme case, her play's probing of the limits of freedom, morality and society has broader relevance. To appreciate that, you need look no further than the 4chan forum, or even Twitter.

But this approach also means it's hard to relate *The Nether* to our world. We know some paedophiles have a compulsive urge to abuse because of, say, a brain injury. Others form support groups to help them resist their urges, reportedly with some success. So it is hard to imagine that what works for one will work for all.

And our virtual technologies cannot yet make online activities substitute convincingly for real ones, which means life without consequences remains science fiction.

But *The Nether* is only just SF. The legality and morality of simulated child pornography is already under debate: does it slake or fuel paedophilia? Virtual children have been created to ensnare paedophiles, yet there have also been suggestions that childlike robots could be used to treat them. And extrapolating from today's "dark net", a world where sites do not appear in any search index, may not be far off.

The Nether is a stark reminder that we have ducked many of the toughest questions about our behaviour in virtual spaces. The play makes a compelling case for fully engaging: its critique of our times is breathtakingly powerful. Let's hope it doesn't prove as powerfully prescient. ■


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Assistant Professor Faculty Position

University of Pittsburgh Cancer Institute
and University of Pittsburgh
Department of Pharmacology & Chemical Biology

Applications are invited for a tenure-stream Assistant Professor-level faculty position at the University of Pittsburgh Cancer Institute (UPCI), specifically a PhD scientist working in the area of breast cancer biology, prevention and/or treatment. The incumbent will have primary appointment in the Department of Pharmacology & Chemical Biology, University of Pittsburgh.

The University of Pittsburgh, School of Medicine ranks among the top 10 NIH-funded academic medical centers, and the department is consistently one of the top 10 NIH-funded Departments of Pharmacology. At UPCI, faculty and lab personnel have access to state-of-the-art shared facilities with animal care, microscopy, mass spectrometry, high throughput drug discovery, translational research and clinical pharmacology analytical capabilities. The UPCI laboratories and shared resources are located in the Hillman Cancer Center and Magee-Womens Research Institute.

Successful candidates should have a track record of extramurally-supported research grant funding, a strong publication record and excellent communications skills. Salary and benefits will be commensurate with experience.

Applicants should provide a one-page statement of research objectives, curriculum vitae, and contact information for three professional references to:

Dr. Maryann Donovan, PhD, MPH
Associate Director for Research Administration, UPCI
C/O Lola Thompson
5150 Centre Avenue, Suite 532
Pittsburgh, PA 15232

Email: thompsonla3@upmc.edu

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Bates College, Faculty Position, Biology

Visiting Assistant Professor of Evolution and Conservation Biology - Biology R2706

Location: **Lewiston, Maine**

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Application Instructions

Review of applications begins 15 March 2015, and will continue until the position is filled. Applicants should submit in PDF format, a cover letter, curriculum vitae, unofficial graduate transcripts, and statements on teaching and research. Please also arrange for the submission of three letters of recommendation, in PDF format. Employment is contingent upon successful completion of a background check.

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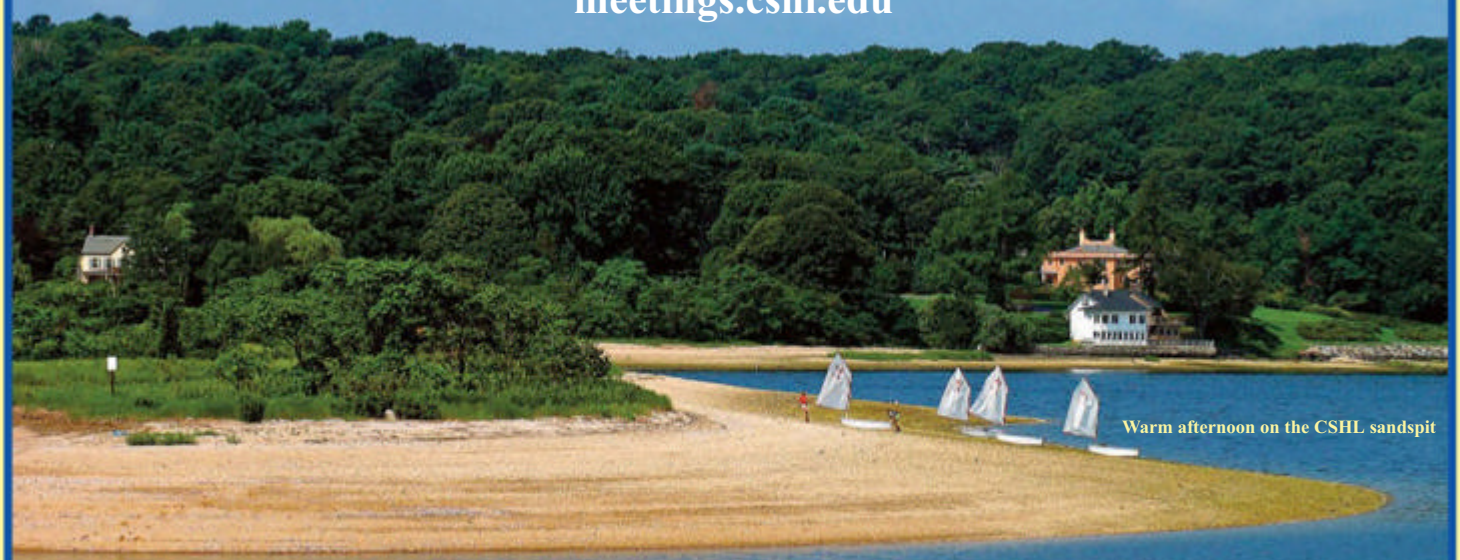

Warm afternoon on the CSHL sandspit

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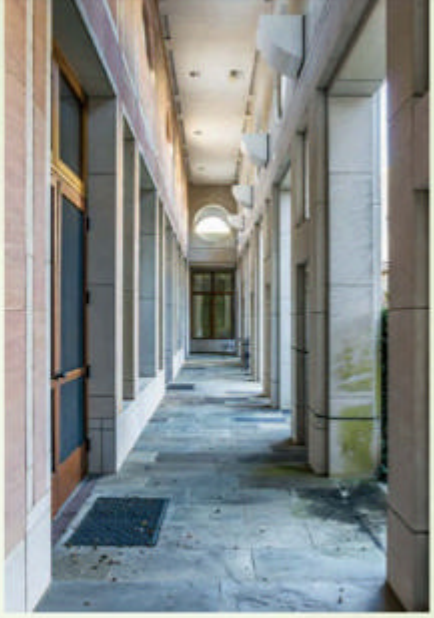

Grant Programs

BIOMEDICAL SCIENCES

Career Awards for Medical Scientists: Five-year awards for physician scientists provide $700,000 to bridge advanced postdoctoral/fellowship training and the early years of faculty service. This award addresses the on-going problem of increasing the number of physician scientists and will help facilitate the transition to a career in research.

Collaborative Research Travel Grants: Provide up to $15,000 in support for interdisciplinary biomedical researchers from degree-granting institutions to travel to a laboratory to acquire a new research technique or to facilitate collaboration.

DIVERSITY IN SCIENCE

Postdoctoral Enrichment Program: Provides $50,000 over three years to support the development of underrepresented minority postdoctoral fellows in biomedical research.

INFECTIOUS DISEASES

Investigators in the Pathogenesis of Infectious Disease: Five-year awards provide $500,000 for opportunities for accomplished investigators at the assistant professor level to study infectious disease pathogenesis, with a focus on the intersection of human and microbial biology. The program is intended to shed light on the overarching issues of how human hosts handle infectious challenge.

INTERFACES IN SCIENCE

Career Awards at the Scientific Interface: Five-year awards provide $500,000 to bridge advanced postdoctoral training and the early years of faculty service. These awards are intended to foster the early career development of researchers with backgrounds in the physical/mathematical/computational/engineering sciences whose work addresses biological questions. BWF has moved to a self-nomination format for this award.

POPULATION AND LABORATORY BASED SCIENCES

Institutional Program Unifying Population and Laboratory Based Sciences: Five-year awards provide $2.5 million to unite population-level and laboratory-based biological sciences. The award supports the training of researchers working between existing research concentrations in population approaches to health and in basic biological sciences. The goal is to establish interdisciplinary training programs by partnering researchers working in disparate environments and intellectual frameworks.

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Innovation in Regulatory Science Awards: Provides up to $500,000 over five years to academic investigators who are addressing research questions that will lead to innovation in regulatory science, with ultimate translation of those results into improving the regulatory process. These awards are intended to provide support for academic researchers developing new methodologies or innovative approaches in regulatory science that will ultimately inform the regulatory decisions the Food and Drug Administration (FDA) and others make.

REPRODUCTIVE SCIENCE

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SCIENCE EDUCATION

Career Awards for Science and Mathematics Teachers: Five-year awards provide $175,000 to eligible science or mathematics teachers in the North Carolina public primary and secondary schools. The purpose of this award is to recognize teachers who have demonstrated solid knowledge of science or mathematics content and have outstanding performance records in educating children. The award is a partnership between the North Carolina State Board of Education and BWF.

Student Science Enrichment Program: Three-year awards provide up to $180,000 to North Carolina nonprofit organizations, including public/private schools, universities, colleges, and museums. This program supports creative inquiry-based science enrichment activities that occur outside the typical school day for K-12 students. The program's goals are to nurture students' enthusiasm about science, expose them to the excitement of scientific discovery, and interest them in pursuing careers in research or a variety of other careers in science.

Promoting Innovation in Science and Mathematics: Awards provide teachers with funding for materials, equipment, and training to conduct hands-on, inquiry-based science and mathematics projects in North Carolina public schools.

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AURA

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The Association of Universities for Research in Astronomy (AURA) seeks a new Director for the Space Telescope Science Institute (STScI). STScI is located at several sites on or around the campus of the Johns Hopkins University in Baltimore, Maryland. STScI is operated by AURA under contract with NASA to conduct the science program of the Hubble Space Telescope (HST) and to develop the Science and Mission Operations Center for the James Webb Space Telescope (JWST). STScI also operates the Barbara A. Mikulski Archive for Space Telescopes (MAST) for NASA. In the case of HST, the Institute solicits and selects observing proposals, supports observers, plans and carries out the scientific observations, calibrates and archives the data, and distributes grant funding. For JWST, the Institute is currently designing and building the ground system, as well as the systems required to align and maintain the telescope and instruments, in preparation for taking responsibility for both mission and science operations in 2019. STScI is, and will be, responsible for the Education and Outreach activities of both of these very prominent missions.

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Materials and nominations should be submitted to **directorsearch@aura-astronomy.org** and addressed to:

Garth Illingworth, Chair
STScI Director Search Committee, C/o AURA
1212 New York Avenue NW, Suite 450
Washington, DC 20005

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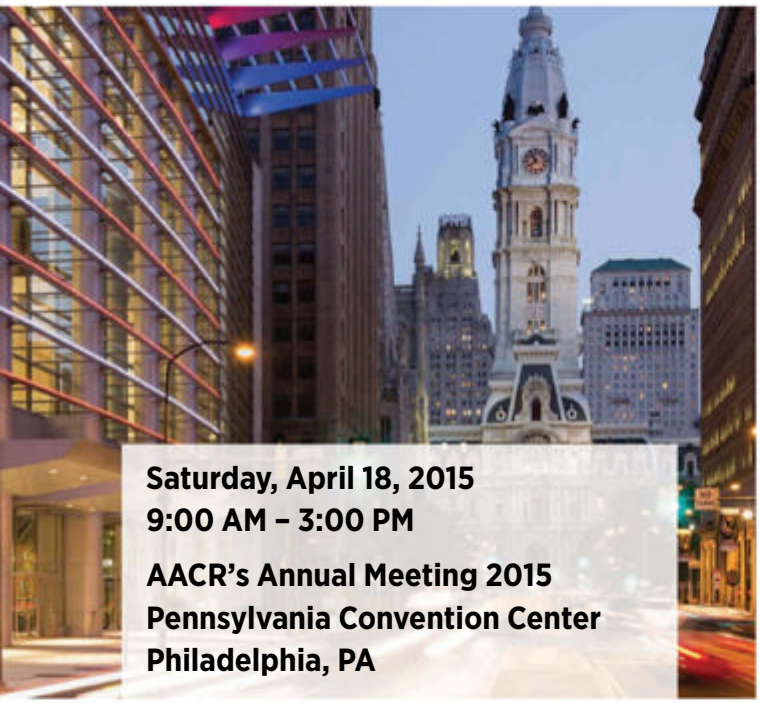

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Heading for trouble

From Haydn Webb
My grandfather's favourite saying was "you cannot put an old head on young shoulders". Soon you might be able to, literally (28 February, p 10).

The wisdom of Alvin Toffler in his book *Future Shock* echoes from the past. We are being dragged into the future behind our technology, out of control and not thinking where it might lead.

Would it not be better for surgeon Sergio Canavero to use this developing technology to help people with paraplegia? In this case, the nerves to be joined would be from the same body, avoiding the problems of rejection. Now that would really bring hope to thousands.
St Blazey, Cornwall, UK

From Brian Horton
Before we get carried away with the idea of head transplants, recall the article in the same issue about people who received bionic replacements for their hands (p 8).

Since we can make human-like robots, perhaps we should use the technique to transplant the head of someone with quadriplegia onto a robot body.

It may be easier to source robot bodies than human body donors with no serious damage anywhere other than the head. Learning to drive a robot body with preset functions might be easier than attempting to relearn the precise movements for a biological one.
West Launceston, Tasmania, Australia

From Bryn Glover
Apart from the technical difficulties of head transplants yet to be resolved, one of the ethical concerns would be whether or not the donor body was the same sex as the original. The implications are intriguing.
Glasshouses, North Yorkshire, UK

From Michael Ennis
Helen Thomson's article reminded me of the sci-fi classic *That Hideous Strength* by C. S. Lewis, in which a shady government research establishment is controlled by a reanimated severed head.

Through this, Lewis addresses the question of what happens to the human soul when you separate the head from the body.
Stroud, Gloucestershire, UK

Truth by consensus

From Paul Dove
There is an obvious problem with Google's plan to rank websites according to their trustworthiness (28 February, p 24).

Doing so by cross-referencing facts may be appropriate for current events, but perhaps not when applied to scientific facts. It is well known that scientific facts have a half-life, as existing research is superseded by the

latest results (22 September 2012, p 36). If Google does not consider this, its search results will not display the most up-to-date but as yet unestablished scientific ideas.
Hampton, London, UK

From Adrian Ellis
Hal Hodson reports that Google's software for ranking pages on their trustworthiness will make its judgement by drawing on a store of facts gathered from the internet. Isn't this circular logic?

How would the Google system handle a statement such as "glass is a liquid"? On the internet, the notion that glass is a slow-moving liquid, resulting in medieval windows that are thicker at the bottom, seems far more prevalent than the truth – that glass is a solid and medieval glaziers placed the thicker end of blown glass sheets at the bottom.

Since nothing on the internet is unanimously agreed, Google's software would have to take the majority consensus. If this happened, there is a good chance that any site dispelling a popular misconception would appear far down the list of search results, making it harder, not easier, for people to learn the truth.

Popular fiction would dominate because the software would add it to the Knowledge Vault and use that reference point to downgrade the truth. Intelligent people can make clever software, but no one makes intelligent software.
Hampton, London, UK

Celestial spectacle

From Martin Savage
I was intrigued by the report of a black hole with a mass 12 billion times that of the sun, which apparently existed 12.8 billion years ago (28 February, p 14).

I can understand how the researchers estimated its distance, and therefore age, from the stretching of light wavelengths. However, the estimation of size is based on apparent brightness.

I wonder how they allowed for gravitational lensing events while the light was en route. After all, even a small lensing event 12 billion years ago would have had a large effect on apparent brightness, and therefore size, as observed now.
Jomtien, Thailand

■ *The editor replies:*
The researchers do indeed address this in their paper. If the black hole was lensed, you would expect to see multiple objects or some other imaging artefacts. However, microwave imagery suggests they are seeing a single object.

Genetic repair

From Ivan Erill
In his passionate case for genetic engineering, Michael Le Page suggests that the limiting factor in germ-line genetic engineering is mainly technological (14 February, p 26).

If only. The real obstacle is appropriate knowledge of the effects that even the simplest genetic manipulations have. So far, we are only good at restoring deleterious mutations.

The proper term for this is patching up, not engineering, and adopting it would provide us with a good analogy to convince opponents that it is right to do so. Rather than engineering a race car, we are simply taking our modest sedan to the repair shop.
Baltimore, Maryland, US

Infected by obesity

From John Harris
While reading Edward Archer's article about the link between maternal inactivity and childhood obesity (28 February, p 32), I wondered if he and other researchers have considered the significance of the adenovirus AD 36. This was described in some detail in *New Scientist* around six years ago (17 October 2009, p 47).

At that time, there appeared to be a strong correlation between infection and subsequent obesity. Comparing the presence of antibodies against AD 36 in obese children and their mothers – who

may have been infected while pregnant – could supply further evidence for Archer's theory.
Richmond, North Yorkshire, UK

Mechanical mate

From Richard Swifte
Your article about an autonomous shipboard firefighting robot built for the US navy (14 February, p 22) caught my attention, particularly because it is bipedal.

This surprises me, since bipedal robots tend to be cumbersome and slow – not ideal for a rolling ship, especially in stormy conditions.

Surely a robot using wheels or a caterpillar tread would be much more stable, and better able to mount steps without losing its balance? Or am I missing something?
Darmstadt, Germany

■ *The editor replies:*
While the researchers admit that balancing on unstable terrain is especially challenging for bipedal robots, the goal is to create a robot capable of working alongside sailors. Such a robot must therefore be designed to have similar agility to humans.

Rose-tinted

From Chris Evans
Paul Bowden says that he doesn't consider pink to be a fundamental colour (28 February, p 55). In this respect he is perhaps more correct than he realises.

"Pinked" refers to petals with a serrated edge. This is the reason that scissors used by dressmakers to produce a serrated effect in fabric are called "pinking shears".

Dianthus flowers are well known for having this type of petal, and are also the "light red" shade Bowden refers to. The close association of these two factors led to the use of the word "pink" to describe the flower's colour.
Earby, Lancashire, UK

Faecal matters

From Malcolm Shute
Once again, *New Scientist* shows that it is greater than the sum of its parts by the juxtaposition of two otherwise unrelated articles.

Writing about microbes in the human environment (7 February, p 38), Andy Ridgway reports that the bacteria found on the seat of a chair are associated with the gut and vagina. Researcher James Meadow concludes that "we're incredibly leaky animals and our clothes are definitely not the impermeable barrier we like to think they are".

The following week, Jessica Hamzelou discusses faecal transplants (14 February, p 8), writing that "the number of people thought to be conducting their own faecal transplants at home is rising".

Maybe buses, trains and theatres were humankind's first foray into facilitating this medical procedure.
La Tour d'Aigues, France

Congressional cure

From James Strunk
Any attempt to reform the US Congress that requires the cooperation of Congress is unlikely to have much impact (14 February, p 22).

Deep reform requires a disruptive change from outside the control of the incumbents. What we really need is a political party – or more than one – that imposes strict controls on itself to limit special interest influence. This would include limits on campaign contributions as well as rules to guarantee transparency and accountability.

To be effective, these rules would not only apply to the party's candidates, but also to all party officers. Even rank-and-file members should be forbidden to make or receive contributions above the limit, and those that violate these rules should be expelled from the party, regardless of seniority.

These rules could be made legally binding by enshrining them in the party's Articles of Incorporation. I believe a political party that shows it is serious about governing itself would gain wide support, and do a better job of governing the country.
Longmont, Colorado, US

From Paul Wood
Oh, the praiseworthy efforts of optimistic youth at the hackathon to fix the US Congress.

Only when constituents give more money to Congress than lobbyists do will Congress be more responsive to them.
Hamilton, New Zealand

Divine deduction

From Alex van de Sande
Mike Paterson places the blame on greed rather than religion for our overstretching of the world's resources (21 February, p54).

But surely the doctrine of many religions to produce as many children as possible is the most basic form of greed. Every extra person produced will want the best life possible, and every parent scrabbles to get that life for their offspring, causing more resources to be plundered.
Chesham, Buckinghamshire, UK

From Tim Stevenson
Chris Ford writes that agnosticism is a more scientifically defensible position than the alternatives (28 February, p 55).

I agree that it is scientific evolutionary atheism that it untenable. How can a creature evolved to swing from trees and then survive in the savannah claim to have a brain capable of deciding on the existence of a god or gods?

For this reason I prefer to call myself, somewhat pretentiously, a "provisional atheist" – one who wishes to have a working hypothesis, and has settled on atheism, but knows he cannot know for sure.
Great Missenden, Buckinghamshire, UK

From Keith Macpherson
I have been agnostic for as long as I can remember, and atheist for most of that time. I'm aware of the supposedly untenable position this puts me in, but I prefer the term a-theist: I am without god.

Even if the ether is swirling with all the deities we have invented over the millennia, I subscribe to none of them. I know that if just one of them turns out to be real I am in a bad position, but on balance, I'll take my chances.
Houston, Renfrewshire, UK

For the record

■ **The light-activated nano-therapy used by Adah Almutairi to treat macular degeneration was tested in animals, but not the human variety (28 February, p 31).**

■ **We wrote that Canada has legalised assisted suicide (28 February, p13). Actually the Supreme Court has ruled that laws criminalising assisted suicide should be changed.**

Letters should be sent to:
Letters to the Editor, New Scientist,
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Fax: +44 (0) 20 7611 1280
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PAUL MCDEVITT

A COMPANY in Hong Kong sends Feedback an invitation to buy "Spy DVR hidden watches". In case we weren't sure what we'd want one for, its website describes many of the watches as "a fun little spy tool that allows you to take video no matter where you go". It also warns: "Do not use this product for any illegal purpose."

But what caught our eye was the sign-off on the email: "Waiting for your earlier comments". Had we been able to comment before it arrived, we would probably have powers that render spy tools unnecessary.

WOULD we need spy tools if we had access to the technology that Harris Steinman points us to at TriVortex.com? Two of the more prosaic benefits claimed by its founder, Brian David Andersen, are "proper hydration via structured water" and the ability to "reduce negative effects of radiation from cell phones". That gave us a good flavour of the evidential rigour here. Then we visited a "position paper" in which he sets out his thoughts and proposals as an "Ebola Syndrome Investigator"…

"How can signals coming from a computer via amplifiers, Ozonated oil suppositories and cellophane wrapped colloidal silver, Vitamin E and Ozonated Hemp Oil assist," he asks, "in stimulating stem cells to neutralize the symptoms of a spider bite and other toxic overloads? How is the Ebola Syndrome connected to spider bites?" How indeed?

THE above may be the most comprehensive collection of fruitloop phrases Feedback has seen. But Brian David Andersen has non-human competition. At least four readers alert us to a website with the enticing welcome: "Namaste. Tired of coming up with meaningless copy for your starry-eyed customers? We can help."

When Jack Kelleher clicked the button on the New Age text generator at bit.ly/bowdlerised-URL, it announced: "Consciousness consists of molecular structures of quantum energy. 'Quantum' means a refining of the cosmic." He would "love to say I fully understand, but as the website noted on my next click, 'Only a visitor of the dreamscape may engender this wellspring of learning'."

HAS anyone, Paul Barrow wonders, used the above-mentioned website that we must refer to as bit.ly/bowdlerised-URL to "save time in creating their fruitloopery-advertising copy?" How could we tell? We asked it. It answered: "Have you found your story? It can be difficult to know where to begin."

WE DO, however, have a new tool in fruitloop-cataloguing. Since 1 March 2011, the UK's Advertising Standards Authority has had the power to rule on claims appearing on websites. So we entered some of our favourite indicative words into its search engine (bit.ly/ASArulings).

The old-fashioned "vibrations" has garnered a mere three complaints, all upheld: one involved a relatively mundane dispute between two makers of electric toothbrushes, one an audio accessory that claimed to eliminate "bad vibrations [man]", and one a device for making homeopathic remedies at home.

The word "homeopathic" gathered 19 further complaints, to which we shall give vanishingly small attention; all but one were upheld, at least in part. There have been five complaints relating to the word "quantum", all upheld. No one has complained about a "tachyon" product… yet.

JUXTAPOSITION can be inspirational. Andrew Shead notes *New Scientist*'s interview with the "elves" who dig up fascinating and unlikely facts for the BBC television programme *QI* (20/27 December 2014, p 40). He anticipates that our mention in the same issue of what he summarises as "lab-grown female anatomy" (p 32) will "smite them between the eyes". He expects that they will latch on to the final sentence: "The surgeon behind the breakthrough is now developing lab-grown penises."

And Andrew predicts, in detail, that "this Elvish research will appear in a 2015 *QI* discussion. Stephen Fry will announce that he is contemplating ordering the extra large in black. One of his guests will assert that he doesn't have enough blood to operate it without swooning."

MEANWHILE, the temporal powers of the above-mentioned BBC programme *QI* appear to be stupendous. Brian Burbage sends an image of the Australian Broadcasting Corporation

offering the chance to watch the episode of 30 November 1899. Fun fact: contrary to the John-Logie-Baird-centric narrative of BBC history, the first patent on television, or at least a television-like system, was granted to Paul Nipkow in Berlin, Germany for his *Elektrisches Teleskop* – and was effective from 6 January 1884.

FINALLY: happy high-precision Pi Day! (3/14/15 9:26:54, US format.)

"No chemicals allowed in this refrigerator," says the sign a safety officer posted in a lunch room at NASA's Goddard Space Flight Center. Dennis Chesters is "still trying to find edible stuff not made of chemicals" to put in it

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Circuit judge

During a blackout, does electricity reverse its flow from the battery of my phone to the charger or power outlet?

■ Mains current is alternating, which means it reverses direction many times a second. This kind of current is easier to generate and is necessary for most motors and transformers to work.

At the heart of all chargers is a component called a rectifier. This blocks the flow of electricity in one direction. As well as blocking the backwards half of the mains cycle, it also prevents your battery discharging back into the mains.

Modern phones contain battery-management hardware and software, which prevents the battery from getting overcharged or charging too quickly. This software would shut down the charger if it tried to discharge the battery, or if the rectifier failed.

Philip Belben
Coalville, Leicestershire, UK

Feeling the pressure

When we took a flight recently, we noticed an unopened packet of potato chips inflate because the cabin air pressure fell with altitude. At the same time, a member of my family commented that they felt bloated and uncomfortable. Is it possible a similar effect was taking place in their gut?

■ The cabin air pressure at 10,000 metres – the cruising altitude of modern airliners – is about two-thirds of normal sea-level pressure . The contents of any gas-filled elastic container will expand due to this difference in pressure. Anybody who has flown with a heavy cold or with blocked sinuses may have experienced this effect, which can cause severe pain on ascending and descending as gasses in the head expand.

"Most of the gas in the gut is in the large bowel. If it expands, there is only one way for it to come out"

To answer the question about gut contents, most of the gas in the gut is in the large bowel and, if it expands, there is only one way for it to come out.

Some find the liberation of colonic miasma one of the surprising pleasures of jet travel. Perhaps on learning this, readers will never view fellow travellers with equanimity. Of course, this would almost certainly be hypocritical.

Philip Welsby
Edinburgh, UK

Scaredy cats

How do ultrasonic devices built to scare away animals such as cats work? Do they mimic a high-pitched sound known to scare such animals, or do they scare them simply by their loudness? Perhaps it is just that the sound annoys the animals as much as it annoys me.
(Continued)

■ The ultrasonic cat repellers mentioned in the question sound similar to devices sold in Australia to repel rats, spiders and crawling insects. I've found these devices work very well.

The salesman said they emit a sound that is annoying, but not harmful, to the pests. He also recommended waiting up to 10 days for them to move out. After installing some in our office, all the spiders had moved out of the toilet cubicles by day four. Occasional visiting spiders remained for less than a day. We saw no fresh rat droppings either.

Years later there was an unidentifiable, annoying screech in one workroom. It occurred at random intervals, audible for 10 seconds every couple of minutes. I had hoped to work there but was driven out after 40 minutes.

After four days I couldn't enter the room at all. I had been conditioned to associate the sound with discomfort. We eventually found the faulty repelling device behind a bookcase. For those who wish to repel human pests, the screech frequency was somewhere between 4 and 6 kilohertz.

Peter Torney
St Kilda, Victoria, Australia

This week's questions

WIBBLY WOBBLY
Lots of people have seen this video of wobbly lamp posts on the M62 motorway in northern England (bit.ly/M62LampPosts). The posts are swaying erratically in the windy weather, and news articles cited vortex shedding as the reason. What does that mean?
Joyce O'Hare
Cleckheaton, West Yorkshire, UK

OPTIC AQUATIC
Humans cannot see clearly under water without goggles. How do aquatic mammals solve this problem?
Emma Jackson
London, UK

NOW, WHERE IS IT?
How can a search engine like Google scan a huge database and come up with answers in milliseconds?
P.J. Nuccio
Lakewood, Washington, US

PREYING ALONE
Many mammals such as wolves and lions are pack hunters. Many fish and cetaceans also collaborate to herd shoals into bait balls, then eat them. So why are there no flock-hunting birds of prey?
Adrian Bowyer
Foxham, Wiltshire, UK

HOTFOOT IT
When I stand in a hot bath, I often have to lift my left foot out quickly because it hurts. But it doesn't seem as painful with my right foot, and I don't have to retract it. I get into the bath left-foot first, and I'm right-handed (and right-footed, back when I played football). Can this be explained?
James Rickman
Totnes, Devon, UK

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THE BAFFLING, TRIVIAL, CURIOUS, OR STRANGE . . .

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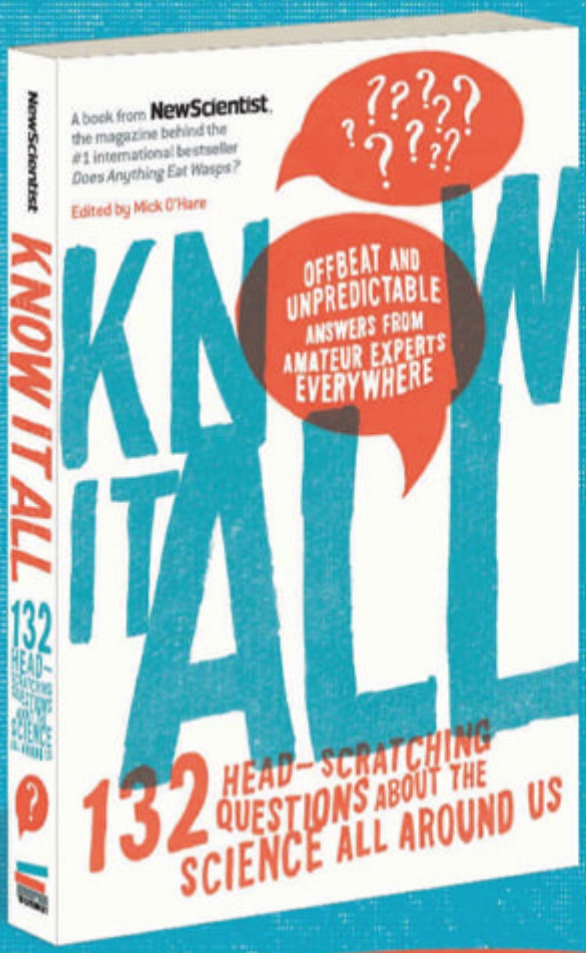

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